NEW SOUTH WALES.

DEPARTMENT OF MINES.

GEOLOGICAL SURVEY.

E. F. PITTMAN, A.R.S.M., Government Geologist.

MINERAL RESOURCES

No. 16.

THE ANTIMONY-MINING INDUSTRY

AND THE

DISTRIBUTION OF ANTIMONY ORES

IN

NEW SOUTH WALES.

BY

J. E. CARNE, F.G.S.,

ASSISTANT GOVERNMENT GEOLOGIST.

With Map, Plates, &c.

SYDNEY: W. A. GULLICK, GOVERNMENT PRINTER.

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Geological Branch,
Department of Mines,
11th January, 1912.

Sir,

I have the honor to submit for publication a pamphlet (No. 16 of the Mineral Resources Series) on "*The Antimony-Mining Industry and the Distribution of Antimony Ores in New South Wales*," by Mr. J. E. Carne, Assistant Government Geologist.

The working of our antimony mines is more or less intermittent, owing to the marked variations which occur at intervals in the price of the metal. At the present time the market price of antimony is low, and mining operations are consequently restricted. Nevertheless, the publication of the information gathered by Mr. Carne will doubtless be found useful when the next rise in the value of antimony gives a stimulus to its production.

I have the honour to be,
Sir,
Your obedient servant,
EDWARD F. PITTMAN,
Government Geologist.

The Hon. A. Edden, M.P.,
Minister for Mines

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I.—INTRODUCTION.

Antimony mining ranks fourteenth in the New South Wales mineral industry as regards total value of production to end of 1910. Owing, however, to unstable market conditions, it has never assumed a permanent character; the output resulting chiefly from spasmodic efforts during "boom" periods of inflation, with intervening seasons of depression and almost cessation. Under local conditions, even normal values afford but modest profit when the metal is unassociated with gold. Hence mining for antimony alone practically ceases when market depressions occur.

The intermittent character of the industry is best exemplified by the following analysis of the output. Boom prices in the periods 1880–1882, 1890–1894, and 1906–1907 were accountable in ten years for an output valued at £245,644, as against £57,215 for the remaining period of the duration of the industry, which dates from about 1874. During the brief boom of 1906–7 the local value of 50 per cent. antimony ore rose to £30 per ton. The present quotation being £7. During the periods of depression values have receded to even £5. In consequence of the limited demand in 1909 and 1910, the local production amounted to only 95 tons 9 cwt., and 96 tons 17 cwt. respectively, chiefly as a second product in gold mining.

As an index to ordinary market values of antimony, compared with boom figures, the following averages have been computed from an interesting table of the average monthly prices of antimony in New York* for 1901 to 1909 inclusive. These disclose remarkable uniformity when the boom years (1906–7) are excluded. For the seven years, 1901–5 and 1908–9, the average price works out at 8·29 cents per lb., whilst for the boom years mentioned the average is 18·96 cents.

F. T. Havard, commenting on the increased import duty to stimulate American production, states† :—

> "But it is probable that an increased production will be effected by nothing less than a considerable rise in the market price. Until the industry shows a great increase in activity and the supply of available hard lead is unable to meet the demands of the trade, we need not expect very much change in the price. For I am convinced that a large proportion of the antimony which was sold during the boom days was used for purposes for which hard lead might be applied.
>
> "One other condition which might affect the price lies in the possibility of the more extensive use of antimonial pigments in Europe which would encourage the French smelteries, now making 60 per cent. of the world's output of refined antimony products, to increase their tonnage of oxides, with a proportional reduction in the amount of refined metal put on the market."

The position was no better in 1910, notwithstanding the duty, the production was believed to be less than 75 tons of ore.‡

In the early eighties antimony reduction works were established at Carangula, Macleay River district, at Hillgrove, and Metz. Works were also started at Taylor's Arm, in the Nambucca district; but for a number of years these have been abandoned. During the recent boom, 1906–7, a smelting plant was laid down by the Metals Smelting Company at Balmain, and about 32½ tons of antimony produced, but these works closed when prices fell.

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* The Mineral Industry, XIX, 1910, p. 37. † *Ibid.* XVIII, 1909, p. 34. ‡ *Ibid.*, XIX, 1910, p. 36.

In the beginning of gold-mining operations at Hillgrove, great difficulty was experienced, owing to the association of antimony with the gold. In 1882-3, Messrs. Newbery, Vautin, and others, patented a process for separation of these metals and saving of the antimony; the antimony being volatilized as oxide and recovered in suitable flues; the gold being recovered from the roasted residues by ordinary crushing and amalgamation.* The method adopted subsequently at Hillgrove was of this character.

As at the present time there is no opportunity for studying antimony smelting in the State, the Writer makes no apology for extracting descriptions from standard works of methods followed in other countries, believing that such will be of local interest, and also the notes on the various industrial alloys and uses of the metal.

* C. S. Wilkinson, Ann. Rept. Dept. Mines, 1883, p. 153.

II.—HISTORICAL.

The progress of discovery of antimony ores in New South Wales, so far as the Writer's research has revealed, has been as follows :—

1846.

In 1846 it is recorded that antimony, cobalt, and mercury, in addition to copper, had been discovered in Australia.*

1852.

In 1852, S. Stutchbury, first Government Geological Surveyor, discovered sulphide and oxide of antimony, (jamisonite and cervantite) near to Campbell's Creek, Upper Meroo River.†

1853.

In 1853, the Rev. W. B. Clarke mentioned that :—"Of minerals besides gold I have met with sulphuret of antimony as near Mount Mitchell (Oban.—J.E.C.) and in the Booroolong Run, as well as in the neighourhood of Gara (Hillgrove.—J.E.C.)." See page 40.

Birkmyre, in a letter to the Melbourne *Argus* of December, 1853, on the mineral resources of Australia, mentions sulphides of bismuth, antimony, and lead, and tin ore.‡

1854.

F. Odernheimer, in 1854, exhibited sulphide of antimony from 3 miles west of the Peel River and 12 miles north of Hanging Rock.§

Amongst the exhibits, G. K. Holden also displayed sulphide of antimony from near Gresford, Paterson River.

1858.

In 1858, S. Hodgkinson described antimony as ranking next to gold in Victoria.‖

1861.

In 1861, G. K. Holden exhibited antimony from Penshurst Estate and other parts of the Paterson River.¶

1867.

Antimony is believed to have been discovered about this date in the Hillgrove district.**

1870.

In 1870, antimony was recorded from the tableland of the Clarence River district, and in the same year antimony sulphide was exhibited at the Intercolonial Exhibition.††

1875.

In this year an antimony lode was discovered 11 miles from Solferino.‡‡

Samples were also received from Pyramul, in the Mudgee district.§§

It was recorded that antimony had been found in several parts of the State, but little attention was given to it.

1876.

In this year antimony was discovered at Lunatic, near Drake. In the following year 36 tons of ore were sent to Sydney.‖‖‖

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* The Mining Journal, 1846, XVI, p. 11. † Report, October 1st, 1852. Parliamentary Papers ‡ Mining Journal, 1854, XXIV, p. 113. § Cat. of Nat. and Indust. Prod., N.S. Wales, exhibited by the Paris Exhibition Commissioners in the Australian Museum, Nov , 1854, p. 54. ‖ A description of the Province of Victoria, 1858, p. 17. ¶ Cat. Nat. and Indust. Prod., N.S. Wales, exhibited in the School of Arts by the International Exhibition Commissioners, Sydney, Oct. 1861, p. 39. ** C. S. Wilkinson, Ann. Rept. Dept. Mines, 1883, p. 153. †† Industrial Progress of N.S. Wales, 1870, p. 79. ‡‡ Ann. Rept. Dept. Mines, 1875, p. 113. §§ *Ibid*, p. 167. ‖‖‖ *Ibid*, 1877, p. 153.

1877.

In 1877 antimony ores were discovered in the Kempsey (Macleay River) district. In this year antimony was discovered by Messrs. Evershed and Thomas at Baker's Creek, Hillgrove.

An antimony lode was also being prospected near Nundle, on the Peel River, a shaft 60 feet in depth exposing a lode from ½ inch to 5 inches in width.

1878.

M.L. 52, Parish Metz, County Sandon, was surveyed for antimony (for Evershed and Thomas) on the 30th October, 1878. Antimony was also discovered between Barraba and Bingara.

1879.

The Munga Creek antimony lodes at Carangara were opened in this year, and smelting works begun, the first metal being produced in 1881.

Antimony was also discovered at Wangwauk, near Cooloongolook, County Gloucester.

1880.

In 1880, three mining leases for antimony were applied for at Gara, near Hillgrove, McBean being reported as the discoverer by the Warden,* though the presence of antimony in this locality had already been noted by the Rev. W. B. Clarke in 1853, as recorded above.

In this year also antimony was discovered on the Aberfoyle River, Armidale district; Orundumby Station, near Walcha; and at Crudine Creek, in the Sofala district.

1881.

In 1881 the Rockwell antimony lode, on the Cudgegong River, about 3 miles from Rylstone, was discovered.

In the same year a mineral lease for this metal was applied for at Razorback, near Ilford.

1883.

Two hundred tons of ore were reported to have been raised from the Hillgrove antimony lodes in 1883.

1884.

Antimony ores were discovered at Bowra, Nambucca River, in 1884.

1885.

Ford's Creek antimony lode, near Gulgong, was discovered in this year.

Small deposits have since been discovered in different localities, but none of commercial importance.

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* Ann. Rept. Dept. Mines, 1880, p. 139.

III.—ANTIMONY.

Physical Properties.

Schnabel and Louis* :—

"Antimony is characterised by its great brilliancy, and by its colour —silver white, with a slight tinge of blue; the latter is increased by the presence of impurities in the metal. When deposited from a solution by zinc, it takes the form of a black powder. When melted antimony is allowed to cool slowly it exhibits a coarsely foliated structure; rapid cooling makes it granular and crystalline. Antimony crystallises, like the amorphous metals, bismuth, arsenic, and tellurium, in the forms of the hexagonal system. Its specific gravity has been determined to be between 6·6 and 6·8.

"Antimony is brittle, and can be easily powdered in a mortar. It is harder than copper. Its coefficient of linear expansion by heat, between 0° and 100° C., is, according to Calvert and Johnson, 0·000985. It melts between 440° and 450° (*Pictet*). In passing from the liquid to the solid state, it does not expand like bismuth does. Carnelly and Carleton-Williams state that its boiling point is between 1090° and 1450° C. According to Demarcay, it boils in a vacuum at the temperature of 292° C. It burns in the air, forming oxides, but can be distilled in a stream of hydrogen.

"When pure molten antimony is allowed to solidify slowly, and without disturbance, under a layer of slag, a fern-line appearance of raised lines, radiating from the centre, appear on the solidified surface of the metal. This is the so-called 'antimony star,' or '*regulus antimonii stellatus*.' On small castings there will be only one such star in the middle of the surface, but larger castings will show many intersecting ones.

"This appearance is not produced in impure antimony, nor in the pure metal, unless it is kept very still and covered during cooling by a layer of slag. As it is generally regarded as an indication of purity of the metal, pure antimony which does not possess it is always re-melted and cooled under the required conditions.

"Its specific heat, as determined by Regnault, between 0° and 100° C. is 0·0508. Its conductivity for heat, compared with that of silver, as 1000, was determined by Calvert and Johnson; along its axis of crystallisation it is 215, and at right angles to this direction it is 192. Its electrical conductivity, compared with that of silver as 100, is 4·29 at 18·7 C., according to Matthiessen.

"Commercial antimony is generally contaminated by small quantities of sulphur, arsenic, lead, copper, and iron. These cause the above-mentioned blue tinge in its colour.

Properties of Antimony and of its compounds, which are of importance for its extraction.

"Antimony is not affected by exposure to air at ordinary temperatures, but at temperatures above its melting-point it oxidises rapidly. Metal which has been reduced from the oxides by charcoal in presence of

* Handbook of Metallurgy, 1898, II, pp. 430–431.

alkalies frequently tarnishes in the air. The cause of this is said to be a small quantity of alkali which is retained by the metal, and absorbs moisture with liberation of hydrogen.

"When antimony which has been raised to a red heat is allowed to fall from a sufficient height on to a plate, it is dissipated in a mass of brilliant sparks, forming a dense white cloud of oxide.

"Antimony is attacked by hydrochloric acid only when it is in the state of very fine powder; hydrogen is then liberated. Sulphuric acid does not attack it when dilute; the hot, concentrated acid, however, forms with it antimonious sulphate, sulphur dioxide being at the same time liberated. Nitric acid attacks antimony, producing, according to its temperature and degree of concentration, a mixture of the trioxide and tetroxide of the metal in different proportions. These oxides are insoluble in the acid.

"*Aqua regia* in the cold dissolves antimony easily, forming the pentachloride.

"In a current of steam at a red heat, antimony is slowly converted into oxide.

"When ignited with nitre and soda, it explodes, forming an alkaline antimoniate; with a smaller proportion of nitre it also forms some trioxide.

"The metalloids, with the exception of boron, carbon, and silicon, all form compounds with antimony.

*Commercial Salts of Antimony.**

Antimony trioxide (Sb_2O_3).—Antimony glass, used as a colouring matter in glass-making, more especially in the preparation of artificial gems.

Antimony pentoxide (Sb_2O_5).—A bright yellow powder, used to replace arsenic acid in the manufacture of analine yellow and analine red.

Antimony trisulphide (Sb_2S_3) and *Antimony pentasulphide* (Sb_2O_5) are used as pigments, the latter principally for vulcanizing india-rubber.

Oxy-salts of Antimony.

The most important of these is *tartar emetic*, or potassium stibnyl-tartarate, C_4H_4 (SbO) O_6, used in medicine.

* Handbook of Metallurgy, 1898, II, pp. 433–435.

IV.—ORES OF ANTIMONY.

The commercial ores of antimony are few, and these alone call for description in an economic work. Antimony, however, enters into combination with numerous other elements, the compounds of which are merely of mineralogical interest. Beyond listing them and indicating their composition, nothing further is attempted in this work.

The following list has been compiled from Dana ("A Text Book of Mineralogy"), Schnabel and Louis ("Handbook of Metallurgy"), and C. Y. Wang ("Antimony: its Chemistry, Metallurgy, and Uses"), but chiefly from Dana.

Commercial Ores.

Stibnite (*Antimonite, antimony glance, grey antimony*).

The most important ore of antimony. Composition—Sb_2S_3; antimony, 71·4; sulphur, 28·6. Orthorhombic. Crystals prismatic, often acutely terminated; vertical planes striated or deeply furrowed longitudinally; crystals often curved, bent in knee-shaped forms or twisted. Common in confused aggregates of acicular crystals; also in radiating groups; massive, coarse, or fine columnar, less often granular to impalpable.

Cleavage highly perfect, the face often striated or bent transversely.

Fracture small, subconchoidal.

Hardness, 2; specific gravity, 4·52–4·62.

Lustre metallic, highly splendent on cleavage or fresh crystalline surfaces.

Colour and streak lead-grey, inclining to steel-grey; subject to blackish tarnish, sometimes iridescent.

Fuses very easily (at 1), colouring the flame greenish-blue. In the open tube sulphurous (SO_2) and antimonial (Sb_2O_3) fumes, the latter condensing as a white sublimate, which before blowpipe is non-volatile.

On charcoal fuses, spreads out, gives sulphurous fumes, and coats the coal white with antimony trioxide; this coating, treated in reducing flame, volatilises, and tinges the flame greenish-blue. When pure, perfectly soluble in hydrochloric acid; in nitric acid, decomposed, with separation of antimony pentoxide.

Changes on exposure by partial oxidation to *Kermesite* ($2Sb_2S_3$, Sb_2O_3), and by further oxidation to *Valentinite* (Sb_2O_3). Antimony ochre (*Cervantite*) also results from its alteration.*

Kermesite.

Composition—Antimony oxysulphide, Sb_2S_2O or $2\,Sb_2S_3$, Sb_2O_3 = antimony, 75·0; sulphur, 20·0; oxygen, 5·0 = 100.

Monoclinic. Usually in tufts of capillary crystals, prismatic, orthodiagonal.

Cleavage—*a* perfect, sextile; thin leaves, slightly flexible.

Hardness, 1 – 1·5; specific gravity, 4·5–4·6.

Lustre adamantine, inclining to metallic.

Colour cherry-red, streak brownish-red; feebly translucent.

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* Dana, 6th Edition, pp. 37, 38.

In the closed tube blackens, fuses, and at first gives a white sublimate of antimony trioxide; with strong heat gives a black or dark red sublimate. In the open tube and on charcoal reacts like stibnite.

Results from the alteration of stibnite.*

Valentinite.

Composition—Antimony trioxide, Sb_2O_3 = antimony, 83·3; oxygen, 16·7 = 100.

Orthorhombic. Commonly prismatic; also tabular; often rounded by striations.

Crystals often aggregated in fan-shaped or stellar groups, in bundles and druses, and as aggregations of thin plates. Also massive; structure lamellar, columnar, granular.

Cleavage—*b* perfect; also *m*.

Hardness, 2·5–3; specific gravity, 5·56.

Lustre adamantine; often pearly; shining.

Colour snow-white, occasionally peach-blossom red, and ash-grey to brownish; streak white. Translucent to subtransparent.

In the closed tube fuses and partially sublimes. Before blow-pipe on charcoal fuses easily, and gives a white coating; this treated in reducing flame colours the outer flame greenish-blue. Soluble in hydrochloric acid.*

Cervantite.

Composition—Sb_2O_4 = antimony, 78·9; oxygen, 21·1 = 100.

Orthorhombic. In acicular crystallisations. Also massive; as a crust or a powder.

Hardness, 4–5; specific gravity, 4·08.

Lustre, greasy or pearly; also bright, or earthy.

Colour, isabella-yellow, sulphur-yellow, or nearly white, sometimes reddish-white. Streak, yellowish-white to white.

Before blow-pipe infusible and unaltered; on charcoal easily reduced. Soluble in hydrochloric acid.

Results from alteration of stibnite and other antimonial ores.*

Senarmontite.

Composition.—Antimony trioxide, Sb_2O_3 = antimony, 83·3; Oxygen, 16·7 = 100.

Isometric; in octahedrons; also granular massive; in crusts.

Cleavage, octahedral, in traces.

Hardness, 2–2·5; specific gravity, 5·22–5·30.

Lustre resinous, inclining to subadamantine.

Transparent to translucent; colorless or greyish; streak white.

In closed tube fuses and partially sublimes. Before blow-pipe on charcoal fuses easily, and gives a white coating; this treated in reducing flame colours the outer flame greenish blue. Soluble in hydrochloric acid.

Results from the decomposition of stibnite and other ores of antimony.*

"Antimony is also a constituent of many lead, copper, and silver ores, especially the latter. Among these may be mentioned *bournonite, zinkenite, jamesonite, plagonite, feather-ore, wolfsbergite, polybasite, proustite, antimonial nickel*, and *antimonial silver, miargyrite, berthierite,*

* Dana, 6th Edition.

boulangerite, and the fahl-ores. Galena also very frequently contain s antimony. In addition to the above, the following are sometimes sources of antimony:—(1) Speiss containing antimony obtained in working copper and silver ores which contain antimony; (2) residues, &c., which contain antimony obtained in liquating antimony glance; (3) dross obtained in antimony smelting. In the working of galena, which contains antimony, the latter metal for the most part alloys with the lead produced, forming the so-called "hard-lead."*

Other Ores Containing Antimony.†

Allemontite, $SbAs_3$.—Antimony, 37·85; arsenic, 62·15.

Ammiolite.—Composition doubtful, but regarded as antimoniate of copper mixed with cinnabar and with other impurities.

Arequipite.—Silico-antimonate of lead.

Arsenstibnite.—Arsenical hydrate of antimony.

Atopite.—Perhaps a calcium pyro-antimonate; iron, manganese, and the alkali metals are also present.

Barcenite.—Antimonate of mercury.

Berthierite.—Probably = sulphur, 30·2; antimony, 56·6; iron, 13·2 = 100.

Bindheimite.—Hydrous antimonate of lead, but analyses vary widely.

Boulangerite.—Sulphur, 18·3; antimony, 22·8; lead, 58·9 = 100.

Bournonite.—Composition—sulphur, 19·8; antimony, 24·7; lead, 42·5; copper, 13·0 = 100.

Breithauptite.—Nickel antimonide, NiSb.

Chalcostibite.—Sulphuret of copper and antimony.

Chanarcillite.—Silver, arsenic, and antimony Ag_2 $(As, Sb)_3$.

Coronguite.—An antimonate of lead and silver.

Dyscrasite.—A silver antimonide—antimony, 27·1; silver, 72·9 = 100; and Ag_6Sb = antimony 15·7; silver, 84·3 = 100; and perhaps other compounds.

Dürfeldtite.—Composition—sulphur, 24·15; antimony, 30·52; lead, 25·81; silver, 7·34; copper, 1·86; iron, 2·24; manganese, 8·08 = 100;

Famatonite.—Composition—sulphur, 29·3; antimony, 27·4; copper, 43·3 = 100. Arsenic replaces the antimony in part. Orthorhombic; isomorphous with enargite.

Freislebenite.—Composition—sulphur, 18·7; antimony, 25·5; lead, 31·3; silver, 24·5 = 100.

Guejarite.—Composition—sulphur, 27·0; antimony, 57·8; copper, 15·2 = 100.

Jamesonite.—Composition—sulphur, 19·7; antimony, 29·5; lead, 50·8 = 100.

Kobellite.—Composition—sulphur, 17·2; bismuth, 29·8; antimony, 8·6; lead, 44·4 = 100.

Livingstonite.—Composition—sulphur, 22·1; antimony, 53·1; mercury, 24·8 = 100.

Meneghinite.—Composition—sulphur, 17·4; antimony, 18·6; lead, 64·0 = 100.

Miargyrite.—Composition—sulphur, 21·9; antimony, 41·2; silver, 36·9 = 100.

Monimolite.—Composition—antimony pentoxide, 36·6; lead protoxide, 57·2; iron protoxide, 6·2 = 100.

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* Schnabel and Louis, Handbook of Metallurgy, 1898, vol. II, p. 437.

† For the initial list the Writer is indebted to C. Y. Wang, Antimony: its chemistry, metallurgy, uses, &c., 1909, pp. 35–44, for composition of the ores to Dana, Handbook of Metallurgy, 6th Edition.

Nadarite.—Composition—antimony, 30·5 ; lead, 52·4 ; chlorine, 9·0 ; oxygen, 8·1=100.

Plagionite.—Composition—sulphur, 21·5 ; antimony, 37·8 ; lead, 40·7= 100.

Plumbostannite.—Composition—sulphur, 25·14 ; antimony, 16·98 ; tin, 16·30 ; lead, 30·66 ; iron, 10·18 ; zinc, 0·74=100.

Polybasite.—Composition—sulphur, 15·0 ; antimony, 9·4 ; silver, 75·6= 100.

Pyrargyrite.—Composition—sulphur, 17·8 ; antimony, 22·3 ; silver, 59·9=100.

Rivotite.—Composition—oxide of antimony, silver, and copper, with lime.

Romeite.—Composition—antimony, 63·4 ; oxygen, 16·9 ; lime, 19·71= 100.

Sarawakite.—May be antimony chloride.

Schneebergite.—Composition—calcium and antimony with a little iron, and traces of copper, bismuth, zinc, magnesia, and sulphuric acid.

Stephanite.—Composition—sulphur, 16·3 ; antimony, 15·2 ; silver, 68·5 = 100.

Tanzite.—Composition—arsenio-antimonate of bismuth.

Tetrahedrite.—Composition—sulphur, 23·1 ; antimony, 24·8 ; copper, 52·1=1100.

Ullmannite.—Composition—sulphur, 15·2 ; antimony, 57·0 ; nickel, 27·8 = 100.

Zinkenite.—Composition—sulphur, 22·3 ; antimony, 41·8 ; lead, 35·9= 100.

V.—METALLURGY OF ANTIMONY.

A. The Treatment of Antimony Glance for the Production of Crude Antimony.

Schnabel and Louis* state that :—

"Ores containing more than 90 per cent. of antimony sulphide are used as crude antimony after being ground, without further treatment. Ores containing less than 90 per cent, and as low as 40 or 50 per cent., are subjected to liquation, if the pieces are of the right size, *i.e.*, larger than hazel nuts, best about walnut size. Small-grained ore and ores with a low percentage of antimony sulphide, are, as pointed out above, worked up for the production of the metal.

"The liquation of antimony sulphide from its accompanying minerals and rocks is possible on account of its comparatively low melting point, below a red heat. The maintenance of the proper temperature is of the greatest importance, for at temperatures above a red heat the sulphide is volatilized and at too low temperatures the residues contain large quantities of antimony. The size of the pieces of ore too has considerable effect on the result; the smaller they are the less complete is the liquation, and the richer are the residues, and further, fine ores lie so close together that the fused sulphide is unable to escape. The best size is proved to be that of walnuts. Fine ores with low percentage of metal give a better result if treated for the production of regulus.

"In commerce great importance is attached to the radiated structure of the product; this is obtained by slow cooling of the liquated sulphide; if it is rapidly cooled this structure is absent.

"The liquation can be done in closed or in open (reverberatory) furnaces. In closed furnaces the ore is contained in pots or tubes, while in the reverberatory furnace it lies exposed on the bed. The closed furnaces use more fuel, and cost more for labour, than the open ones, but they extract a larger proportion of sulphide than the latter, which lose considerable quantities by votalisation and oxidation."

1. Liquation in Closed Furnaces.

"The melting is done in pots or tubes. If pots are used, they are either directly surrounded by the burning fuel, or are heated by the flame from a fire-place. The latter method is always adopted where tubes are used. Pots are worked intermittently, but pipes permit the adoption of continuous work with corresponding economy in fuel."

(*a*) *Liquation in Pots.*

"This method requires a high consumption of fuel, but has the advantage that it can be conducted at the mine, on account of the simplicity of the furnace. It is therefore used where the ores are rich and fuel (wood or coal) is cheap at the mine.

"The pots are made of fireclay, and hold from 11 to 56 lb. In the bottom of each there are four or five holes 0·4 to 0 6 inch in diameter, through which the melted sulphide escapes. These rest on receivers of burnt clay, which collect the liquid crude antimony. The receivers, in order to ensure the slow cooling of the contents, are bedded in sand,

* Handbook of Metallurgy, 1898, II, pp. 433–444.

ashes, or breeze. The pots are placed in a row, there being sometimes several of these at regular distances apart; twenty or thirty pots form one row. The space in which they are placed is enclosed by a low wall of dry masonry. The space between the crucibles and between them and the wall is filled with fuel, coal or wood being used. The liquation takes from two to twelve hours, according to the size of the charge. At its conclusion the pots are lifted off the receivers, emptied, and again charged, and placed in position. The receivers are in some places emptied after each charge, and in others left till they are full. The residues contain, as a rule, not less than 12 per cent of sulphide. . . .

"*Pots heated by a flame* permit of greater economy of fuel, and also facilitate the working of poorer ores, but the labour is more severe on the workman than in the method previously described.

"These pots are placed in a furnace on each side of the fire, or are arranged in a circle round it; the receivers for the melted sulphide are either placed below the bed of the furnace, surrounded by sand and out of contact with the flame, or they are placed entirely outside the furnace, being connected with the liquation pots by a clay pipe."

(*b*) *Liquation in Tube Furnaces.*

"These furnaces can be arranged with vertical or horizontal tubes, but the latter arrangement does not appear to have been adopted.

"The tubes are arranged in groups of four, each group being placed in a chamber with three grates; they extend to the outside of the roof, where they are closed, while working, with a cover, and are 3 feet 3 inches high, 10 inches diameter at the upper end, and 7¾ inches diameter at the bottom, their walls being 0·6 to 0·8 inch thick. They rest on a fire-clay slab pierced with holes for the escape of the liquid sulphide. . . . . The charge for each tube is 5 cwt. of ore, and it takes three hours for complete liquation; the yield is 50 per cent. of sulphide. For the production of 100 cwt. of sulphide, 64 cwt. of coal are necessary; the tubes last twenty days each."

2. Liquation in Reverberatory Furnaces.

"This method of liquation possesses the merit of being the least expensive in fuel, labour, and repairs, but it leads to considerable loss of sulphide by volatilisation. It can, therefore, only be adopted where it is a question of producing large quantities of crude antimony with great rapidity, where fuel is dear, and where the cost of mining the ore is low, and therefore loss of sulphide may be disregarded.

"The liquation furnace may be constructed like that for the removal of lead from copper, or like the German refining furnace. In the latter case, a tap-hole must be introduced at the deepest point of the bed. The liquated sulphide will escape through the tap-hole into the receiver placed in front of it. Towards the end of the process the tap-hole is closed, and the furnace strongly fired. The sulphide still in the ore now collects below the layer of slag which forms, and is tapped. The slag is afterwards withdrawn through the side door. . . .

"The liquation residues contain upwards of 20 per cent. of sulphide of antimony; it is contained not only in the interior of the pieces, but also covers them as well, in the form of a glaze. . . .

"The liquation residues, when sufficiently rich, are worked up for antimony regulus."

B. The Treatment of Antimony Glance and other Antimony Ores for the Extraction of Metallic Antimony.*

"The treatment of antimony-glance (stibnite.—J.E.C.) for the extraction of metallic antimony can be done either by the roasting and reduction method or by the so-called precipitation method.

"The former consists of an oxidising roasting of the ore, followed by a reduction of the oxide formed during the roasting, by means of coal, with the addition of fluxes and covering materials (soda, potash, glauber salts). The process may be performed in shaft furnaces, reverberatory furnaces, or (in rare instances) in pot furnaces.

"The precipitation method is carried out by smelting antimony-glance (or crude antimony) with iron and fluxes. The antimony is separated in the metallic state with formation of sulphide of iron. It may be done in a pot, or in reverberatory furnaces.

"The roasting and reduction method is less expensive than the precipitation method, and is suited to the working of the poorer ores and liquation residues; it is, therefore, to be preferred to the precipitation method. The latter is only suited for the smelting of rich ores and of crude antimony, and is more expensive in practice on account of the high coal consumption and labour cost; it is only rarely adopted.

"The antimony ores, other than antimony-glance, are not treated by independent special methods. When sulphuretted, they are worked together with antimony-glance. If they are oxidised ores, they are subjected to a reduction process, *i.e.*, they are mixed with antimony-glance after it has been roasted."

I. The Roasting and Reduction Process.

"This may be resolved into (1) the roasting of antimony-glance and (2) the subsequent reduction of the oxide of antimony formed in roasting.

(*a*) *The Roasting of Antimony Glance.*

"The roasting of antimony-glance can be so conducted that the product shall principally consist of either the stable tetroxide or the volatile trioxide; in the latter case, the trioxide would be collected in a suitable arrangement for condensation. The former method of roasting is more usual; the latter, which has been named 'volatilising roasting' (*verflüchtigende röstung*), has been suggested for the extraction of antimony, but appears, so far, to have only been adopted for the preparation of the trioxide for use as a pigment.

"The chemical changes which take place during the normal oxidising roasting of pulverised antimony-glance, having for its object the conversion of the sulphide into the tetroxide, are the following, if the correct conditions of temperature and air admission are observed:—

"When the temperature is raised to the proper point (not much over 350° C.) the atmospheric oxygen converts the antimony trisulphide into sulphur dioxide and antimony trioxide. A part of the latter is further oxidised to pentoxide, and this, combining with some of the trioxide, forms the tetroxide. Antimonic acid is formed in the presence of the oxides of the metals, and combines with them to form antimoniates."

". . . With pure antimony-glance, and the correct temperature and quantity of air, the product of roasting is principally the tetroxide, but it always contains antimony glass and undecomposed sulphide. If

* Schnabel and Louis, Handbook of Metallurgy, 1898, II, pp. 445–447.

there are foreign sulphides and arsenic compounds in the ore, antimoniates, arseniates, and sulphates of the foreign metals are found in the roasted mass.

"Since antimony sulphide and antimony trioxide melt at a dark red heat and form antimony glass, and since, furthermore, they are both volatile, the maintenance of the proper temperature is of the greatest importance. According to Bidou it is not allowed to exceed about 350° C. ; at lower temperatures the sulphide would not be decomposed. At temperatures only slightly beyond 350°, the mass begins to frit together, thereby preventing the penetration of air to the interior. At still higher temperatures the trioxide volatilises.

"By regular rabbling, the fritting of the mass is prevented, even at the higher temperature, and the presence of gangue in the ore also tends to obviate the same difficulty. The richer the ore, the more difficult is it to roast it ; with rich ores it is impossible to prevent to some extent both the liquation of a portion of the sulphide and the formation of flue dust, which latter consists almost entirely of antimony trioxide and tetroxide, antimony sulphide, arsenic compounds, and carbonaceous matter. It is, therefore, only possible to raise the temperature for the purpose of oxidising any unaltered sulphide, after the greater part of the sulphide has been converted into tetroxide. Properly roasted ore should appear of a reddish colour while in the furnace, and of an ashy grey colour on cooling ; further, while in the furnace it should feel soft under the rabble, and free from any fritting together. If the admission of air during the roasting be limited, the volatile trioxide, and not the tetroxide, is formed.

"The so-called *volatilising roasting*, which is only designed to form and volatilise the trioxide, requires for its execution a restricted air supply and a higher temperature. Steam at a high temperature also effects the formation of the trioxide, with the simultaneous production of sulphuretted hydrogen. This method of roasting was proposed by Hering, for the treatment of poor ores and residues from the liquation of crude antimony, but does not appear to have been practically applied. Since the arsenic contained in the ore, when roasted, forms compounds which are more volatile than antimony trioxide, it is possible to separate the two products by intercepting the latter. This method of roasting also has the advantage that the gold and silver, which nearly always exist (with other metals) in these ores, remain in the residue and can be extracted. . . .

"If the oxide [from the volatilising roasting—J.E.C.] is to be used as a pigment—a very limited application of it—it must be of exceptional whiteness, and to ensure this the roasting is conducted in muffles. Oehme obtains this purity of tint by roasting the sulphide in a restricted air supply with admission of steam ; this is said to produce an oxide of great purity in white sublimed needles, sulphuretted hydrogen being formed at the same time."

(*b*) *The Reduction Process.*

"The object of this is to reduce the oxide (either tetroxide or trioxide) to metallic antimony. If coal alone be used for this purpose, a large proportion of the antimony will be lost through volatilisation as trioxide, and any antimony sulphide still remaining in the roasted ore

will not be decomposed. Substances are therefore added to the charges which, on account of their easy fusibility, form a protecting cover and prevent the volatilisation of the antimony; these also assist in the formation of fusible slags, and separate the metal from any sulphide of antimony present. The substances which are most advantageous for this purpose are such as remove the impurities from the antimony, and also serve as a refining medium. Potash, soda, glauber salt, and other alkaline substances are used.

"The reduction is carried out in reverberatory furnaces, in shaft furnaces, and occasionally in crucibles in pot furnaces.

"The *reverberatory furnace* process is simple and easily controlled, but is accompanied by considerable loss of antimony, and is therefore only used where ores are rich and raw fuel cheap.

"The *shaft furnace* method causes less loss of antimony than the former one, and is less expensive, but presents technical difficulties. It is necessary to form a protecting slag which shall be sufficiently thin and fusible to protect the separated antimony from volatilisation and from oxidation by the air blast. It may be employed for ores which are too poor in antimony to be worked in reverberatory furnaces.

"Antimony ores are only exceptionally worked in crucibles, as the cost of fuel and labour is very high."

*Reduction in Reverberatory Furnaces.**

"The loss of metal in these furnaces is high, amounting at the least to 12 per cent.; indeed Helmhacker says it may rise as high as 30 or 40 per cent. . . .

"The furnace-beds are egg-shaped, 7 ft. 10 in. long, 5 ft. 3 in. wide in the centre, and 3 ft. 4 in. wide at the fire-bridge. The bed is a deeply hollow one, built of fire-brick, and slopes from every part to the tap-hole in one of the longer sides. The tapping-pot is placed below the tap-hole, level with the floor of the shed. The height from the bed to the roof in the centre is 3 ft. 3 in. . . . . .

" . . . At the end of the system of condensing chambers is the main chimney. The dust obtained from these chambers contains up to 50 per cent. of antimony. The charge for the furnace consists of 400 to 500 lb. of roasted ores, oxidised ores and flue dust, 90 to 100 lb. of a flux consisting of salt, smaller quantities of soda, and sometimes a small quantity of glauber salt, 65 to 75 lb. ground charcoal, and 220 to 230 lb. of slag from the previous charge; this slag contains principally common salt.

"The fluxes are introduced into the furnace first, and fired; when in a state of tranquil fusion, about an hour after charging, the introduction of the other ingredients of the charge is commenced. These are added through the working door in portions of about 44 lb., at intervals of fifteen minutes, and well stirred in. After the addition of each portion a scum is produced, which is drawn off through the working door. When the last portion has been added and stirred in, the furnace is strongly fired, and the charge tapped, the whole process occupying from four to six hours. During the process the antimony is separated from its oxygen and sulphur compounds by the action of charcoal and soda, gangue is slagged by the soda, and the foreign metals present are carried into the slag as sulphides by the action of the sulphide of soda resulting from the reduction of glauber salt by the charcoal. The salt added to

* Schnabel and Louis, Handbook of Metallurgy, 1898, II, pp. 451–453.

the charge acts, like the glauber salt and soda, as a flux and as a cover, but it also conveys some of the foreign metals into the slag in the condition of chlorides.

"The fuel consumption is 5–6 cwt. per charge, and the loss amounts to 14 or 15 per cent. of the total antimony contained in the ore.

"The slag and metal collect in the tapping-pot, and after they have become solid are lifted out together, after which the antimony regulus is freed from slag and broken up."

*Reduction in Shaft Furnaces.**

"This method, as well as the reverberatory furnace method, was practised at Bouc and at Septémes, in France, and at Oakland, in California; at the present time it is in use at Banya, in Hungary.

"At Bouc and Septèmes ores containing 30 to 40 per cent. of antimony were roasted in reverberatory furnaces, and smelted in shaft furnaces, which were worked on the 'spur'-principle, with covered 'eye'. They are 10 feet 10 inches high, 2 feet 7 inches to 3 feet in depth, and 1 foot 11 inches wide, and had three tuyeres. No information is available as to the composition of the charges. In twenty-four hours 2 to 2½ tons of ore were worked, and the coke consumed was half the weight of the ore. The crude metal produced contained 92 to 95 per cent. of antimony, and was refined.

"At Banya the materials for the production of antimony were :—

Roasted ore containing	48–49	per cent.	of antimony.
Unroasted oxidised ores	46	,,	,,
Unroasted liquation residues from the production of crude antimony, containing	21·4	,,	,,
Roasted residues, containing...	23·0	,,	,,
Flue-dust	56·0	,,	,,
Refinery slag.....	25·0	,,	,,

"These are smelted together in shaft furnaces 19 feet 7 inches high, the diameter being 4 feet 7 inches at the mouth, and 3 feet 4 inches at the tuyere; each furnace has five water tuyeres, and is constructed with a closed crucible; 3,000 cubic feet of wind are supplied per minute at a pressure of 12 inches of water. A campaign, or 'run,' lasts three weeks. The charges are of two different compositions, A and B below :—

	A	B
	lb.	lb.
Roasted ore	1,213	1,323
Roasted residues from liquation	1,654	1,323
Ore moulded into lumps with lime	441	.....
Flue-dust moulded into lumps with lime.....	220	.....
Unroasted ore	.....	220
Oxidised ores	.....	220
Unroasted liquation residues	.....	220
Limestone	1,323	1,764
Foul slags from same work	882	882
Slags from refinery	.....	441
Impure antimony (III below).....	.....	220

"The mixing of lime with the fine ore and flue-dust is only done during the first eight or ten days of the campaign, after that time they can be added in their natural state without prejudice to the process. The quantities of lime used at first are, for fine ores, 10 per cent. by weight, and for flue-dust 7 per cent.

* Schnabel and Louis, Handbook of Metallurgy, 1898, II, pp. 454–455.

"These two charges are used alternately, so that two charges of mixture A are followed by charge B, and in twenty-four hours a total of 30 cwts. is put through the furnace. The unrefined antimony obtained is of three grades, of the following compositions :—

	I	II	III
Antimony, per cent.	90·92	73·80	65·04
Iron	6·23	16·66	23·80
Sulphur	2·85	8·42	10·46
	99·10	98·88	99·30

"The grades I and II are refined; the grade III is returned to the furnaces in the charges as shown above.

"The slags produced in this operation have the following composition :—

	I	II
SiO_2	46·9	45·9
CaO	34·6	31·4
FeO	15·1	19·9
Sb	0·5	0·9

Slags which are not clean and contain large quantities of antimony are returned to the furnace."

*Reduction in Pot Furnaces.**

"The reduction of roasted ores in crucibles in pot furnaces is, on account of its high cost, only adopted occasionally where a small quantity is required, and where rich ores or crude antimony are available.

"The roasted ore is fused with 10 per cent. of its weight of crude argol, or with charcoal or anthracite, and potash and soda, in fire-clay crucibles heated in a wind furnace, or in a galley furnace. The melted metal is cast in iron moulds coated with tallow or thin fire-clay cream.

"According to Knab each crucible contains 26·5 lb. of roasted ore with 10 per cent. of charcoal, and 7·15 per cent. of salt, or soda. The pots are arranged ten or twelve in each furnace, and each pot turns out four or five charges in twenty-four hours. The consumption of coal is 70 to 80 per cent. of the weight of the ore, and the life of each pot is seven or eight charges.

II. The Precipitation Method of Reduction.†

"This method is applicable only to rich ores and crude antimony. It consists in replacing the antimony in the sulphide of antimony by iron, thus separating the antimony in the metallic state, and forming sulphide of iron at a comparatively low temperature. It is impossible, however, to completely separate the sulphide of iron from the antimony, on account of the high specific gravity of the former, and therefore sodium sulphate and carbon are added in order to produce sodium sulphide, which forms with the iron sulphide a fusible slag of low specific gravity which easily separates from the antimony. Common salt is used in England instead of sodium sulphate and carbon. Iron is best used in the form of turnings, shavings, or tin-plate cuttings. In the case of the latter, the tin they contain does no harm. The proportion of iron must not be too high in the case of ores containing sulphides of lead and arsenic, because the antimony would not only be contaminated with iron, but also with the lead and arsenic reduced by the iron from their respective compounds.

* Schnabel and Louis, Handbook of Metallurgy, 1893, II, p. 456. † *Ibid.*, pp. 456-459.

"With reference to this it must be borne in mind that where sodium sulphate and carbon are used, part of the iron is consumed in decomposing the sodium sulphate. It has been found by experiment that where 10 per cent. of glauber salt and 2 to 3 per cent. of coal are used, 44 per cent. of iron is required; this figure is given by Karsten, but Liebig states that 42 per cent. is sufficient, and Hering uses only 40 per cent. Berthier uses the following proportions:—Sulphide of antimony, 100; forge scale, 60; soda, 45 to 50; coal dust, 10. The iron in all cases separates out as the mono-sulphide FeS, or, according to Schweder, as the sulphide Fe_8S_7.

"In England it is usual to add excess of iron in order to secure the separation of all the antimony in the ore; this, however, is only done with ores which are free from lead and arsenic. The excess of iron alloys with the antimony, and is removed by subsequent fusion with more sulphide of antimony.

"There is some loss of antimony in the precipitation method, owing partly to volatilisation of the sulphide and partly to the fact that the slags carry some away. Karsten states that the yield where crucibles are used is 64 per cent., Berthier, 65 to 67 per cent.; the theoretic yield is 71·5 per cent.

"This method is carried out, as a general rule, in pot furnaces, but reverberatory furnaces are sometimes used in spite of the inevitable loss of antimony; shaft furnaces have only been applied experimentally; crucible furnaces are adopted in England, Hungary, and other places.

"In English works, of which the principal ones are Messrs. Cookson and Co., Newcastle-on-Tyne, Messrs. Hallet and Fry, Johnson Matthey, and Pontifex and Wood in London, ores containing 50 to 55 per cent. of antimony are worked. An antimony-iron alloy is first produced by fusing the sulphide in graphite pots with excess of wrought iron. This ensures the extraction of all the antimony contained in the ore. This alloy is then freed from the iron it contains by fusing it in graphite pots with sulphide of antimony, and the metal obtained again fused with suitable materials in graphite pots in order to refine it. All three operations take place in the same furnace. The ore, broken to the size of hazel-nuts, is smelted with wrought iron, tin-plate cuttings, salt and slag from the same process, or with skimmings from a subsequent ore. Each pot holds a charge of 46·3 lb. of ore containing 52 per cent. of antimony, 17·6 lb. of iron, 4·4 lb. of salt, and 1·1 lb. of slag or skimmings. The iron usually consists of 14·3 lb. of cuttings compressed into a cake, and 3·3 lb. of turnings and borings. The ore, salt, slag, or skimmings, as the case may be, and the borings, are mixed together and placed in the pot, and the cake of cuttings is placed on the top as a cover. . . . . The smelting of a charge for the production of the antimony-iron alloy takes three hours, or a little less. When the charge is smelted, the contents of the pot are poured into conical moulds, and a new charge is introduced. When the contents of the mould are cold, the matte and slag are removed from the surface of the antimony by beating it with a hammer, and are thrown away.

"The antimony-iron alloy, technically known as "Singles," contains 91·63 per cent. antimony, 7·23 per cent. iron, 0·82 per cent. sulphur, and 0·32 per cent. insoluble matter.

"The iron in the alloy is removed, as already stated, by fusion with sulphide of antimony. To ensure complete removal of the iron, excess of the sulphide is used. The iron sulphide separates as a matte, and

common salt, or sometimes soda ash, is added as a cover and to flux the sulphides. The charge consists of 92·6 lb. of broken regulus, 7·5 to 9 lb. of liquated sulphide, and 4·4 lb. of salt, and the same furnace is used as in the former process. The fused mass is stirred from time to time with an iron rod, and the time required for a charge is about 1½ hours. At the conclusion of this fusion the slag and matte are removed with an iron spoon, and the contents of the pot poured into a conical cast-iron mould, the matte and skimmings being added to subsequent smeltings of ore.

"The metal, which at this stage is known as 'star bowls,' contains 95·53 per cent. antimony, 0·18 per cent. iron, and 0·16 per cent. sulphur. The presence of the sulphur, which is due to the excess of sulphide used in the second fusion, may be recognised by the appearance of small glistening patches in the crystalline pattern on the surface of the casting.

'In order to remove the sulphur, and to produce the so-called 'star antimony,' the 'star bowls' have to be further refined. To do this a fused mixture of potash and sulphide of antimony is added to the metal in a graphite crucible in the same furnace as was used in the previous operations. The charge is 92·6 lb. of metal and 8·8 lb. of the fluxes, the latter being added after the fusion of the metal. The pots are placed in the hottest part of the furnace, as close as possible to the fire, and, when the fusion is complete, the contents of the pot are stirred with an iron rod and poured. . . .

"The loss in this process is 10 per cent. of the antimony contained in the ore, the greater part of which is due to volatilisation during smelting. Condensing chambers are connected with these furnaces, and are cleaned out four times a year, when a large quantity of white flue-dust is obtained. This contains 70 to 72 per cent. of antimony, and is mixed with coal dust, and smelted with charges of ore."

(c.) *The Refining of Antimony.**

"The refined antimony, as already stated, usually contains sulphur, iron, arsenic, and copper, and frequently lead as well. These impurities, with the exception of lead, can be eliminated partly by oxidising and slagging agents, partly by sulphurising agents, and partly by chlorinating agents. Sulphur is removed by fusion with soda or potash or antimony glass (antimony oxy-sulphide). Arsenic is converted by soda or potash into arseniate of soda or potash, and can thus be removed. Copper and iron are converted by sulphide of antimony into sulphides; the conversion is facilitated by the addition of soda or potash, or of glauber salt and charcoal. The sulphides of iron and copper form a slag with the sulphide of sodium, which results from the reduction of the glauber salt, and with the soda or potash present. They can also be removed easily by antimony glass.

"Common salt, carnalite or magnesium chloride, when added, cause the volatilisation of some of the foreign metals as chlorides, and slags the others. A large quantity of antimony, however, is volatilised at the same time, so that, on the large scale, this method is attended with great loss of metal.

* Schnabel and Louis, Handbook of Metallurgy, 1898, II, pp. 461–462.

"The above mentioned methods do not eliminate lead, because metallic antimony separates lead from its oxide or sulphide; lead can only be separated from antimony by chlorodising, which causes great loss of antimony, and even then the lead is only incompletely removed."

Mitscherlich suggested that the lead should be removed from the sulphide of antimony before the latter was smelted, by fusing the sulphide with 4 per cent. iron. By this means the whole of the lead, and a comparatively small amount of antimony, would be removed. From all this it is obvious that the best way to produce an antimony free from lead is to use an ore which is itself free from that impurity.

"It has already been pointed out that, in commerce, antimony is judged by the appearance of the fern-like 'star' on its surface. This characteristic is not exhibited by impure metal, nor by the pure metal if any part of the surface has been exposed during solidification, nor if the slag covering set before the metal, nor if undecomposed soda or potash came into contact (even in minute quantities) with the surface. Ingots which do not show the star must, if impure, be refined; and, if pure, be recast, and allowed to cool under the proper conditions. Small ingots will show only a single large 'star,' while larger ones will show several, and will have a fern like pattern on their side.

"The refining is done either in crucibles in pot furnaces or in reverberatory furnaces. The former method requires a greater fuel consumption, and therefore, for the production of large quantities of refined antimony, reverberatory furnaces are preferred; but the loss of metal in the process amounts to between 20 and 30 per cent. At many works in England the refining is performed as a part of the process of extraction."

The Herrenschmidt process of antimony smelting (patented in France, April, 1908, No. 386,107), is probably the latest development in the metallurgy of antimony. The patentee was associated with reduction works at Carangula, near Kempsey, in the early beginning of the industry in this State. His latest process is described at length by Chung Yu Wang,* who assisted in some of the experiments with this latest improvement in the volatilising process for low-grade antimony ores. It is claimed that not less than 90 per cent. of the metal contained in the ore is recovered as oxide by this process.

Six tons of ore, containing 10 to 15 per cent. of antimony, can be treated every twenty-four hours, with a consumption of 4 to 5 per cent. of gas-coke, or 6 to 7 per cent. of charcoal.

With ores containing 18 to 20 per cent. of antimony, 4½ tons per twenty-four hours can be treated with a consumption of 5 to 6 per cent. gas-coke, or 7 to 8 per cent. charcoal; any gold present being almost all recoverable in the scoria.

For each apparatus four workmen are employed in the twenty-four hours, and 3 horse-power is used for the ventilators and pump.

The cost of treatment, stated generally, amounts to about 70 francs (£2 18s. 4d.) per ton of oxide produced. The complete apparatus costs 10,000 francs (£416 13s. 4d).

* Antimony: Its Chemistry, Metallurgy, Uses, &c., 1909, pp. 98-102.

F. T. Havard*, writing of the Chatillon and Herrenschmidt processes, states :—

> "Both methods are economically successful under good management, and both lack, by a great measure, perfection. Chatillon relies largely on condensation by water, in towers and scrubbers ; Herrenschmidt condenses the major part of the fume in dry settling flues and chambers, and catches the last remnants of antimony by passing the gases through a centrifugal washer, which at the same time induces the draft. Both are experimenting with textile filters, and are using the organ-pipe settling-chamber system."

Writing of the "Progress in the Metallurgy and Determination of Antimony," the same author states :—†

> "The new Chatillon furnace is very attractive. A special feature is the double shaft, each section having two compartments, one placed directly above the other. In the upper compartment, most of the volatilisation of the stibnite and fritting of the gangue is accomplished. On leaving this chamber the charge drops into the lower compartment, heating the air in its indirect passage to the top of the upper compartment, and perfecting the volatilisation of the antimony, so that the scoria, which is withdrawn, contains 1 per cent. and less of the metal. Since the Auvergne furnaces work best with an excess of air, the second chamber should act as a valuable economiser in heating the draft. With an excess of air, the reduction of the higher oxides by SO_2 is less likely to be accomplished, and consequently there will be less sulphuric acid formed to harm the condensing system. The disadvantage of using an excess of air lies in the fact that Sb_2O_4 and Sb_2O_5 are more likely to be formed than the desired Sb_2O_3 which condenses easily and makes an excellent paint. Furthermore, even with a warm blast the use of an excess of air reduces the temperature at the top of the furnace, and in this way helps in condensing the oxide fume.
>
> "The high recovery attending the use of the volatilising process has confirmed the belief which we have expressed of the relative ease with which antimony fume may be condensed."

New South Wales Antimony Smelting Works.

Antimony smelting is reported to have been commenced at Hillgrove in 1878, a small furnace being erected in that year by an Armidale syndicate. In this year 41 tons of antimony metal are included in the State exports.‡

In 1879 erection of smelting works was begun in connection with the Carangula antimony lodes near Kempsey, on the Macleay River. These were completed in 1880, and rebuilt in 1883.

In 1881 smelting works were erected on Bischoff's conditional purchase at Hillgrove, at a cost of about £1,000 ; 270 tons of ore being smelted.

In 1883 C. S. Wilkinson mentions the Hillgrove Antimony Smelting Works belonging to Messrs. Guigni, Friedmann and Kessler, of Armidale, which during the year was compelled to close owing to fall in values.

In 1890 the Eleanora Antimony Smelting Plant consisted of five furnaces capable of turning out 50 tons of crude per week.

In 1906 a smelter was being erected at Metz, near Hillgrove.

Small furnaces were erected at different dates, in the Nambucca district—as at Taylor's Arm—to deal with the local production, but only ran for short campaigns.

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* The Mineral Industry 1909, XVIII, p. 37. † *Ibid*, pp. 37, 38.
‡ Ann. Rept. Dept. Mines, 1878, p. 43.

Of the early smelting plants and the processes adopted, nothing has been recorded, and these works have long been dismantled.

The following particulars of the Metals Smelting Company, Balmain, and its operations during the antimony boom of 1907, have been furnished by Mr. W. H. C. Lovely, M.A.I.M.E., who acted as superintendent and metallurgist :—

"In December, 1906, the Metals Smelting Company, Limited, was formed for producing star antimony (antimony regulus) from Australian ores. The plant was erected at Booth-street, Balmain, and smelting started 11th March, 1907. The plant consisted of one reverberatory furnace, with flues, condensing chambers, and attendant machinery.

"The ore was obtained chiefly from Hillgrove, but consignments were also received from Kempsey, Nambucca, Hill End, Wellington, Barraba, and Nundle.

"The Hillgrove ore was mostly bought on the field on sight as customary; but the other ore, from scattered sources, was bought on assay upon arrival at the works.

"The smelter usually treated from 30 to 50 cwt. of ore per day, producing star antimony in one operation, but later it was found more economical to first produce impure metal, and refine it periodically in large charges.

"Low-grade ores, down to 15 per cent. antimony, were also treated, though smelters abroad will not buy ore under 50 per cent. This enabled miners to realise on quantities of ore otherwise valueless to them.

" Usually twelve men were employed on the smelter till October, 1907, when the furnace was shut down for repairs; the last run being for six months continuously in blast.

"The furnace was lined with English magnesia bricks, which lasted the whole period, whilst firebricks used whilst waiting the arrival of the others, were eaten through in a fortnight by the strongly basic slag used.

" During 1908, alloys were extensively made up at the works in additional plant erected for the purpose; and a new and larger furnace was constructed with improvements; and a smaller one specially for starring the metal after smelting and refining in the larger furnace.

"Smelting, however, was not restarted as the metal had fallen from £125 per ton to £30; and the supply of ore from the mines practically ceased.

"The Company's capital was all absorbed in depreciation in value of the metal in transit to London and in stock. Owing to these causes, the Company decided to discontinue business, and went into liquidation.

"The average recovery of metal from the ore was 90 per cent., which is higher than usual, especially from low-grade ores.

"Smelting ceased about April, 1908.

	tons	cwt.	qr.	lb.
"Total ore smelted (approximate)... ...	179	8	2	11
,, antimony produced...	32	9	1	7

VI.—ALLOYS OF ANTIMONY.

Schnabel and Louis.*

"Antimony alloys with most metals, making them brittle. It is added to lead to harden it. When alloyed with tin it renders it silvery in appearance, increases its hardness, and raises its melting point.

"The most important alloys of antimony are *type-metal*, which consists of lead, tin, and antimony, or of only lead and antimony; *hard-lead*, produced by working lead ores which contain antimony, and which consists of lead and antimony in very varying proportions; *Britannia-metal* and *white*—bearing—or *antifriction metal*, which consists principally of antimony and tin, with addition of lead, copper, zinc, bismuth, and nickel. *Britannia-metal*, which is used for the manufacture of teapots, spoons, plates, &c., contains, according to Ledebur, tin 85 to 93 per cent., antimony up to 10 per cent., and copper up to 3 per cent. English *plate-pewter* and *Queen's-metal* are similar alloys."

Uses.

F. T. Havard† states that—

"In addition to its wide use in the form of alloys and pigments, antimony salts are applied in the forms of the trioxide for making enamels, of the trichloride in bronzing iron, of the trisulphide in pyrotechnics, of the penta-sulphide in vulcanising and colouring rubber, and of the chromate (Naples yellow) in the ceramic arts. Many of its salts are also valuable medicines.

"Of the leading three white metallic paints, white lead, white antimony, and zinc white, white antimony has the greatest covering capacity, and the most pleasing appearance."‡

Paints.

"The trioxide Sb_2O_3 is itself of excellent colour, fire, and covering capacity, while the mixture of barium sulphate and antimony trioxide which is obtained by adding barium carbonate to a hot solution of antimony oxide in sulphuric or sulphurous acid, is of equal value. Of the three leading white metallic paints, white lead, white antimony, and zinc white, white antimony has the greatest covering capacity, and the most pleasing appearance.

"Many patents have been granted for processes of making the yellow, brown, and red sulphide paints."§

Schnabel and Louis state that‖—

"Sulphide of antimony is used to a large extent, especially as a paint for ship's bottoms; it is therefore the object of preparation in a special industry, which consists in simply liquating it from other minerals and rocks which accompany it in its ores. The product of this process is called *crude antimony*.

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* Handbook of Metallurgy, 1898, II, p. 436. † The Mineral Industry, 1909, XVIII, p. 43.
‡ *Ibid.*, p. 41. § *Ibid.*, p. 41. ‖ Handbook of Metallurgy, II, 1898, p. 438.

Antimony Preparations and their Uses.

C. Y. Wang* :—

"The principal uses of antimony, arranged in the order of importance, are as follows :—

1. Alloys.
2. Pigments and paints.
3. Medicine.
4. Colouring matter in glass-making and in the preparation of artificial gems.
5. Colouring matter in pottery-making.
6. Colouring matter for the manufacture of cloth and paper.
7. Mordants.
8. Corrosive for dyeing.
9. Vulcanising rubber.
10. Coating articles.
11. For the manufacture of aniline yellow and aniline red.
12. For the fabrication of dice-boxes, for the cartridges of the new fire-arms, and other objects for artillery uses.
13. Miscellaneous uses.

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* Antimony : Its Chemistry, Metallurgy, Uses, &c., 1903, p. 145.

VII.—DESCRIPTIVE REGISTER OF OCCURRENCES IN NEW SOUTH WALES.

Aberfoyle, Parish Rampsbeck, County Clarke, on Aberfoyle River. In 1880 a lease for antimony mining was taken up at Aberfoyle, about 36 miles north-east of Armidale.* In 1907 attention was directed to this lode during the brief antimony boom; and a small parcel of ore was marketed.

Abington Creek, M.L. 5, Parish Sandy Creek, County Hardinge, in Sutton's Gully, 24 miles east north-east from Bundarra, and 20 miles north-west of Armidale. Antimony ore recorded in this locality.

Alderman's Lode, M.L. 6, Parish Carnham, County Drake. Discovered by A. Alderman, who prospected only. Sunk on by T. Bassetti to a depth of 18 feet. Width of lode about 4 inches, chiefly cervantite.

Armidale, 25 miles north. G. W. Card records native antimony from this locality. Massive, with a crust of oxide.†

Ashford, near, in County Arrawatta. In 1890 antimony ores were reported near Ashford—probably near Bonshaw—where sulphide of antimony in small quantity occurs in Permo-Carboniferous rocks, about 1 mile south of Bonshaw Hotel, close to Inverell-road. Several small openings were made exposing a little ore sparsely distributed.

In 1891 assays of samples from Ashford (?) yielded from 31·93 to 50·72 per cent. of antimony.

Australian Broken Hill Consols Mine.—E. F. Pittman, Government Geologist, states that:—

> "In the Australian Broken Hill Consols Mine the association of antimony with silver is notable, and quite a number of antimonial silver minerals have been found. The most important of these is dyscrasite, which occasionally occurs in large masses, and was at first mistaken for native silver."‡
>
> These masses are further described as up to a ton in weight, and pseudomorphous after chalybite." §

Bellingen River.—Warden Ducat in 1888 reported:—

> "About 2 miles south-west from this field [Deep Creek.—J.E.C.], and nearer the south arm of the Bellingen River . . . . an antimony reef was discovered, and five applications for mineral leases lodged on the supposed line of lode. D. Anderson and party on No. 88–6 have done much work. They have a shaft down 50 feet, and have uncovered a large reef of rich antimony. They have about 100 tons or more at grass, but have not put any quantity on the market."‖

C. S. Wilkinson, Government Geologist, and W. H. J. Slee, Chief Inspector of Mines, in the following year inspected this discovery, and reported:—

> "In the slate ranges, about 3 miles northerly, is Anderson's Reef, which has been sunk upon to a depth of 70 feet, and is from 20 to 24 inches wide. It contains oxide and sulphide of antimony, with native antimony, which Mr. Anderson informed us yielded, on assay, at the rate of 14 oz. of gold per ton. About 1 mile southerly Messrs. Powell,

* Ann. Rept. Dept. Mines, 1880, p. 139. † Records Geol. Sur. N.S. Wales, VII, 1902, pt. 2, p. 43.
‡ Mineral Resources of N.S. Wales, 1901, p. 246. § *Ibid.*, p. 247. ‖ Ann. Rept. Dept. Mines, 1888, p. 106.

Buchanan, and party are also prospecting two antimony lodes, which afford encouraging prospects, the ore occurring with quartz in intrusive granitic dykes. As we observed many of these dykes in this locality, we believe that when they are prospected other auriferous antimony lodes will be found, and probably lead to the profitable employment of many miners."*

Bingara, between Bingara and Barraba.—In 1878 a sample of stibnite and cervantite in quartz, purporting to come from Bingara, was assayed for 48·9 per cent. of antimony.

In 1896 land was taken up for antimony mining near Oaky Creek, on the Bingara–Barraba road, which probably represents the earlier discovery.

In 1907 a small parcel of antimony ore was obtained from Cobbadah, probably in the same locality.

Antimony is also reported 14 miles west of Bingara, and at Golden Gate, 8 miles from Bingara.

Bowra, near Nambucca River.—The Warden also reported discovery of antimony near Bowra, showing rich specimens.†

In the following year the site was visited by Messrs. C. S. Wilkinson and W. H. J. Slee, who reported :—‡

"The town of Bowra is situated at the head of the navigable waters of the Nambucca River, and several antimony reefs have been found in the locality. About 2½ miles northerly from Bowra is O'Donnell's reef. It is a well-defined breccia quartz reef, from 2 to 5 feet thick, containing sulphide of antimony and pyrites. A shaft has been sunk upon it to a depth of 80 feet. It now requires a bulk sample of several tons of the stone to test its value, and the reef should also be opened a little further to the south on its strike, south 15° east.

"On a branch of the Buccra–Bendinni Creek, about 18 miles westerly from Bowra, Mr. P. McHugh and party are prospecting a quartz and antimony reef, which is from 3 inches to 3 feet wide. It is a true fissure reef, striking from north 20° east to north-east, formed along the line of a fault in the strata, and will be a permanent one. We saw two other parallel faults within a distance of half a mile, in which antimony will probably be found.

"In the Parish of Medlow, 13 miles south-westerly from Bowra, Mr. D. Graham and party have discovered a quartzite reef crossing a creek, flowing into Taylor's Arm Creek. It varied from 3 inches to 3 feet thick, and contains sulphide of antimony. In places the antimony ore occurs in solid masses, 3 inches thick ; in others it is more or less scattered through the quartzite in small crystalline particles. It is nearly vertical, striking north-north-east to north-east, and could readily be worked by tunnelling into the side of the hill. A few small antimony veins branch off from it on the west side. A smaller quartzite reef occurs about 100 yards further down the creek.

"As the antimony ore occurs in bunches irregularly distributed in the reefs their value can be better tested by raising bulk samples from different points along the course of the reefs than by sinking deep shafts, as the reefs are not likely to change in character in depth. The country consists of broken ranges, some attaining an elevation of over 3,000 feet above sea-level. They are composed of altered shales and sandstones, traversed by quartz veins and granitic dykes, but the latter are not so numerous as those in the country between the Nambucca and Bellingen

* Ann. Rept. Dept. Mines, 1889, p. 204. † *Ibid.*, 1884, p. 95. ‡ *Ibid.*, 1889, p. 204.

Rivers. The geographical formation is favourable for the occurrence of other similar antimony reefs. There is little doubt but that the reefs of this district will afford profitable employment to many small parties of miners, and that large quantities of antimony will be produced. It is reported that the antimony ore nearly always yields, on assay, some gold and silver.

In 1890 the Warden* reported that—

"The very numerous discoveries of antimony-bearing veins, extending from near the sea coast at the Bellingen, through by Pickett's Hill to Bowra, and the head waters of the Nambucca and Taylor's Arm, over the dividing range from Macleay River to Carangula Mines, cover a very extended line of country. . . . . .

"Not much progress to report in most cases; the ore turned out bunchy. J. Mackay and others put in two tunnels in face of hill; the lower one has now a depth of 110 feet (below the outcrop.—J.E.C.) with only small veins of antimony showing in the rock.

"About 100 yards up the hill another drive has been opened, and is in about 35 feet. 12 tons of good ore were taken from it, but it has pinched a lot.

"In Parish Medlow two or three leases show better prospects, the lodes of antimony are more defined and of greater body. . . . .

"Altogether about 100 tons of ore have been shipped from these mines.

From Taylor's Arm and Bowraville the following outputs of ore are recorded in the Annual Reports of the Department of Mines for the years quoted, but they are not regarded as complete :—

1890—40 to 50 tons despatched from Nambucca.
1892—280 tons, valued at £3,920.
1893—Fair quantity of ore despatched—smelting works being erected.
1894—370 tons, valued at £1,372.
1895—50 tons, valued at £500.
1896—30 tons, valued at £210.
1899—191 tons, valued at £815.
1902—15 tons.
1905—Small parcels—not defined.
1906—Small parcels—not defined.

Broken Hill.—Antimony is present in the sulphide levels of the Broken Hill silver-lead-zinc-lode. In 1906 the Broken Hill Proprietary Company produced a quantity of antimonial lead at their Port Pirie Smelting Works.

In 1907, the amount of this alloy was returned as 652 tons.

Dyscrasite (silver antimonide) occurred in massive blocks in the Australian Broken Hill lode.

Bull Creek.—Macksville Division, Nambucca River, County Raleigh (*see* Bowraville). In 1891, 14 tons of antimony ore were raised from a tunnel at Bull's Creek.

Bungonia.—Samples purporting to come from Bungonia were assayed in 1880 for 28·42 per cent. of antimony.

Carangula Antimony Mines.—Munga Creek, about 4 miles from its junction with the Macleay River, Parish Burragong, County Dudley.

In 1877 the Kempsey (Macleay) district was recorded as an antimony locality, and in 1879 the Munga Creek antimony lodes were opened, the Mining Registrar reporting that a number of persons held mineral licenses

* Ann. Rept. Dept. Mines, 1891, p. 127.

and were obtaining and despatching to Sydney considerable quantities of antimony ore; also that works and machinery were in course of erection.* Two leases were also applied for at Warrell Creek, and at Wangwauk, near Coolongolook.

In 1910 Mr. Geological Surveyor Lamont Young, F.G.S., visited the scene of operations near Kempsey, and furnished a report dated 3rd April, 1880,† from which the following particulars are extracted :—

"The antimony deposits are situated on the Munga Creek, 4 miles above its junction with the Macleay River, and occur in rocks which, judged from their lithological character, are of Devonian age (since identified on palæontological evidence as Permo-Carboniferous, Lower Marine.—J.E.C.). In the neighbourhood of the mines the strata have been highly disturbed, causing the country to assume a broken character, a point which, taken in connection with the variation exhibited in the strike of the lodes, and the frequent appearance of 'slickensides,' may be considered as favourable to the presence of mineral deposits of an irregular nature. Up to the present no workings of any extent have been prosecuted in the locality, but what little has been done tends to confirm this opinion.

"The antimony ore occurs in irregular bunches, occasionally of a considerable size, enclosed in a quartz matrix, which forms the chief constituent of the lodes. The latter have a general strike between north and north-east, one notable exception being the Victoria Reef; they are much inclined to break into strings, or leaders, and to vary in size. The antimony minerals are represented by 'stibnite,' or sulphide of antimony, and 'cervantite,' or oxide of antimony; the latter will, I believe, be found replaced by the sulphide when lower portions of the lodes are opened out; at present it will serve by a judicious combination with the sulphide, charcoal, and a flux, to produce metallic antimony without the use of scrap iron. The stibnite appears of a high degree of purity, and the cleavage faces of the crystals, seen on breaking up masses of the ore, are remarkably brilliant and large. The following is the result of an analysis by Mr. Dixon of a specimen of mixed sulphide and oxide for gold and silver :—Gold, 2 dwts. 10 grs.; silver, traces per ton; a fine-grained variety is occasionally found.

"By the enterprise of Messrs. Herrenschmidt and Ward, a smelting furnace has been erected on the spot, and the former gentleman has practically demonstrated the value of the minerals of the locality for the production of the finest antimony. These gentlemen, who have some lodes in the immediate proximity to their works, have let the same on tribute to working miners, a proceeding which has been followed by other claim-holders. From the nature of the deposits and the value of minerals they contain, it is apparent that a large extent of lode must be available in order to insure a constant supply of ore. This can only be done by the acquisition of a considerable area of ground, or the amalgamation of several small claims."

The following is a brief summary of the principal claims on which work has been begun. (Extracts.—J.E.C.)

Herrenschmidt and Ward's Claim.—Shaft 28 feet. Lode strikes N. 10° W., dip west at 76°, width 25 inches. Lode shows patches of ore composed of stibnite and cervantite, with a quartz matrix.

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* Ann. Rept. Dept. Mines, 1879, p. 186. † *Ibid.*, 1880, pp. 250-252.

Shaft No. 2, depth 15 feet. Lode split into leaders, showing 6 inches wide at north end without mineral. At south end mixed sulphide and oxide 4 inches wide. Lode striking N. 10° E. vertical.

Bolt's Reef, Victoria Claim.—Lode 30 inches wide. Strike N. 72° E.; nearly vertical. Ore mixed sulphide and oxide. Ten tons sold to smelters.

Thomas' Claim.—70 yards south of Victoria. Strike N. 58° E., dip north 32° W. at 75°. Composed of quartz strings with occasional patches of stibnite and cervantite, total thickness 49 inches. Some distance south is a north and south lode, dipping west; poor.

Walford's Claim.—About 300 yards north of Victoria Claim, strike N. and S., dip west at 55°. Width 10 inches.

Young Australian Claim.—Three lodes of same character, consisting of small quartz veins with occasional bunches of ore, consisting of mixed sulphide and oxide. Strikes vary from N. and S. to N. 30° E., and the dips from 70° to 76° to the west. None of these lodes are well defined. Country sandstone,

Lady Mary Claim.—West of the Young Australian. Reef 4 inches wide, dipping north-west. Not encouraging.

De la Force's Claim.—Strike N. 30° E., dip west at 65°. Width not well defined. Large blocks of ore occur in clay in sandstone country. A considerable quantity of ore extracted.

Kavanagh's Claim.—North of De la Force's Claim. Outcrop of a lode opened, but no work worthy of remark done.

In 1881, the Carangula Antimony Company were running the antimony industry at Carangula, purchasing all ores raised, and producing "star antimony." When in full work 200 to 300 men were employed. The Company, however, got into financial difficulties, and hands were reduced to about thirty.

The Company sank twelve shafts to depths of 40 to 80 feet, and raised a considerable amount of ore.

Bolt's Mine yielded about £1,500 worth of ore from two shafts, 63 and 85 feet deep.

In 1882 a few hands were employed, but the furnaces were idle; 120 tons of first-class ore and 80 tons of second were despatched to Sydney.

In 1883 there was a revival. The Carangula Company were carrying on vigorously under the management of Mr. E. H. Becke. The main shaft was continued to 134-feet level, several small veins being cut in sinking. Lode driven on 80 feet at the 120-feet level. Good ore struck in western drive. Six other shafts on the property were in 60 to 80 feet, and three tunnels from 175 to 245 feet. The furnaces were rebuilt, and plant remodelled. 2,000 tons of ore reported at grass—6 tons of star antimony despatched. Expenditure, £9,000.

Active work continued during 1884, eighty men being employed. Smelting works in operation; additional furnace under construction at close of year. Main shaft deepened to 200 feet, No. 2 to 137 feet; three others from 64 to 96 feet.

Output, 30 tons "star"; 40 tons "regulus"; 125 tons crude. The fall in values, however, soon caused a cessation in work; apparently nothing was done in 1885, 1886, 1887, and 1888. Towards the end of the latter year, however, the furnaces and plant were again being put into order, though nothing further eventuated, as the mines were idle in 1889 and 1890.

In 1888, Messrs. Lark and Sons, Moore-street, Sydney, exhibited at the Melbourne Centennial Exhibition a large trophy of star antimony, regulus, crude, and ore from the Carangula Mines and Smelting Works.

In 1891, about 100 tons of ore were despatched.

In 1893, the output of ore from the Kempsey district was estimated at 866 tons, valued at £7,466 10s., presumably from Carangula and neighbourhood.

Clarence District.—In 1870* it was recorded that antimony had been found on the tableland of the Clarence district, probably referring to the antimony lode at Lunatic Reefs, in County Buller, or possibly from Horse-shoe Bend, near Lionsville, or Pucka, near Yulgilbar. A sample of ore from this district was exhibited by Thomas Ireland.†

Cobbadah.—In 1907, Parkinson, of Cobbadah, sent 3¼ tons of antimony ore to the Balmain Smelting Works, which assayed 60 per cent. metallic.

Collom Collom Creek Lode.—Parish Carnham, County Drake, about 3 miles south-south-westerly from Lionsville. Discovered by J. F. Adams, and opened to a depth of 75 feet. Lode averaged 6 inches in width; 3 or 4 tons of 33 per cent. ore despatched, containing about 7 dwt. of gold per ton in addition.

Corry and Wilson's Lode.—M.L. 2, Parish Carnham, County Drake. Discovered by T. Bassetti. Opened by tunnel. Average width of lodestuff, about 6 inches. About 10 tons of dressed ore despatched.

Crudine Creek.—Antimony was discovered at Crudine in 1880, blocks of pure ore, but no defined lode, being reported.‡

In 1884 a sample of cervantite from this locality was assayed for 62·43 per cent. of antimony, gold and silver being absent.

From Elkin and Company's 50-acre lease 50 tons of ore were raised during the year. The lode ranged from 8 to 12 inches thick.

In 1886 the site was visited by C. S. Wilkinson, who reported that—

> "The antimony mine, near Crudine Creek, occurs in a line of fault of Silurian slates. It is a breccia lode of 8 inches to 3 feet wide, with quartz veins; and the ores (sulphide and oxide of antimony) occur in it in lenticular patches. Only prospected to a depth of about 30 feet. Reported that, from 65 tons raised, 15 tons of oxide and 2 tons 18 cwt. of sulphide yielded 70 and 60 per cent." Samples taken by Mr. Wilkinson of the breccia lodestuff yielded 48·8 per cent. of antimony, but neither gold nor silver. The lode dipped south-west at 40°.§

Donald's Gully.—G.L.'s 200, 201, 202, 210, 211, Parish Jenny Lind, County Buller, near Pretty Gully, and 14 miles north-east of Drake. Held by L. and P. Fordham. Worked originally by Alex. Stuart, afterwards by Chas. Hammet, who took out much gold, but experienced difficulty in separating the antimony without losing gold. The lode strikes north-west, vertical. Usually of slight width, but occasionally widening to lenses. Country, slate; now worked for gold.

Dorrigo.—Antimony reported to occur 8 miles from Beale's Down Settlement, 12 miles north of Dorrigo, and 1 mile from Beale's Down Creek; 1 mile from Hewitt's selection. Parish Allen, County Fitzroy.

Eurunderee, Mudgee District.—J. E. A. Wurth reported discovery of antimony in this locality in 1909.‖

Ford's Creek, 6 miles south of Gulgong.—Examined by C. S. Wilkinson in 1886, who reported:—

> "At the head of Ford's Creek, 6 miles south of Gulgong, three small breccia lodes or short 'blows,' containing sulphide and oxide of antimony and a little quartz, have been opened to a depth of 5 feet. They occur in irregular fissures, formed where the strata (Silurian clay-slates and sandstones) have been fractured. The antimony occurs in irregular

* Industrial Progress of N.S. Wales, 1870, p. 343. † *Ibid*, p. 79. ‡ Ann. Rept. Dept. Mines, 1880, p. 56.
§ *Ibid.*, 1886, p. 138. ‖ Misc. Papers, Mines Dept, 09-320..

bunches, and, as it is impossible to determine the extent of the rupture without sinking upon it, the probable value of the lodes can only be ascertained by actual prospecting. A sample of the breccia lodestuff gave, on assay, 36·37 per cent. of antimony, and neither gold nor silver; but the lodestuff, after crushing, might be concentrated to yield about 60 per cent. of antimony.

In 1887 Mr. Wilkinson further reported:—

"There are two small lodes cropping out at the surface about 100 feet apart. The uppermost lode is about 6 inches thick, and dips south 15°, east at 20°, and has been exposed in an open cutting 6 feet deep and 30 feet long. The lower lode, which has been opened to a depth of 5 feet, is about 6 inches thick, and dips south 25° east at 27°, but in one place at 60°. They are breccia or rubble lodes, consisting of broken fragments of slate rock associated with quartz, and contain oxide and sulphide of antimony."*

A little work was done on these lodes in 1889, but soon ceased.

Four-mile Claim.—On Four-mile Creek, 4 miles south of Pretty Gully, Parish of Jenny Lind, County Buller. Four-mile Creek is a tributary of Emu Creek, about 10 miles north of Drake.

Lode consists of quartz, with antimony ore in slate. Not of value.

Fraser's Gully.—Three miles S.S.E. of Ashford, Parish Ashford, County Arrawatta, on east side of Fraser's Creek. Antimony reported to occur here.

Gara.—*See Hillgrove.*

Gobondry.—Antimony is reported to occur 18 miles east of Gobondry.

Goodeman Creek.—In 1889 a 40-acre lease was taken up for antimony mining, where ore of good quality was reported.†

Gresford, Paterson River.—This site was quoted as an antimony locality in 1877. In 1907 a small parcel of ore was obtained during the antimony boom.

G. K. Holden, in 1854, displayed antimony sulphide from near Gresford at the Paris International Exhibition,

Hell's Hole, Mudgee line.—In 1883 a sample from a locality thus described was assayed for 40·26 per cent. of antimony, and gold at the rate of 2½ ounces per ton, which brings it near the Razorback ore, near Ilford.

Herbert Park.—Cameron's Creek Gold-field, about 11 miles north-west of Hillgrove. Described by C. S. Wilkinson in 1889 as "Devonian sedimentary, intruded by dykes of granite, which, like those of Hillgrove, have gold and antimony reefs associated with them. One of these, sunk on to 119 feet, was 3 feet 9 inches thick, containing pyrites and free gold; probably identical with the occurrence 1½ miles from Herbert Park, Parish Donald, County Sandon.

Hill End.—In 1907 A. Le Messurier, Hill End, forwarded 2½ tons of antimony ore to the Balmain Smelting Works from this locality, which assayed 58 per cent.

Hillgrove District.—Antimony ores were noted in this locality (Gara) by the Rev. W. B. Clarke as early as 1853, but it was not until early in 1880 that it was really commercially discovered. In that year the Warden reported that the discovery "led to the issue of twenty-three mineral licenses and thirteen applications for mineral leases at Gara Falls. Three gold-mining leases of land at the same place have been applied for. Messrs. Moore and Company, who are now mining there for antimony, have sent to Sydney 50

* Ann. Rept. Mines Dept., 1887, p. 144. † Ann. Rept. Dept. Mines, 1889, p. 66.

tons of ore. A large quantity, the amount of which I have not been able to ascertain, was previously sent to the same place by Evershed and Company. (A. Evershed and J. Thomas discovered antimony at Baker's Creek, close to the present Hopetoun reef, in 1877, and applied for a lease (M.L. 52) in March, 1878; which was surveyed in October of the same year. J.E.C.) The lode in one of Moore and Company's two shafts is from 10 to 16 inches wide. The ore from one of the shafts is dark in colour, and, as I am informed by Mr. Moore, has yielded on assay 56 per cent. of antimony and 1 oz. 2 dwt. of gold to the ton."*

In 1881 the local mining registrar reported that antimony in large quantities had been discovered in different parts of the district, the chief being Gara and Hargrave's Falls.

Hargrave's Falls.—(Top of Swamp Creek Falls, Hillgrove.—J.E.C.) From the mines in this locality 346 tons of ore are reported to have been raised during the last half of 1880, some of which was sent to Sydney and some smelted on the ground. The site is probably identical with that now known as Brereton's, which comprised original Portions 122, 123, and 124, Parish Metz, County Sandon.

From Brereton and Gallagher's about 75 tons of ore were raised in 1880, chiefly from the surface; the ore being richer at the bottom of the falls, a tramway was constructed to convey it to the upper level.

Most of the ore had to be brought up the steep slopes by pack-horses.

In 1883 the late Government Geologist, C. S. Wilkinson, examined the new field and reported* :—

> "The country generally consists of rocky hills of no considerable height; but Baker's Creek, which flows through it in a southerly direction, suddenly descends into a large precipitous ravine, called 'The Falls,' which is about 1,600 feet in depth. This abrupt valley, which, like that of the Gara Falls, opens into another of greater magnitude, is a splendid instance of the effects of the denuding agencies which have eroded the slopes of the Great Divide.
>
> "The formations of the locality are granite and metamorphosed sedimentary rocks, probably of Devonian age, judging from their lithological character; but as yet I have not been able to discover any fossils by which their age could be determined.
>
> "The antimony reefs crops out in places, not only on the hills, but also at various levels on both sides of the deep valley. The principal ones which have been worked are Moore's, Brereton's, and the Eleanora reefs. The latter reef occurs on the highest part of the eastern side of The Falls valley, and has been traced in a north-westerly direction for a distance of nearly half a mile and into the valley. It traverses altered slates, and dips E. 40° N., at an angle of 80°.
>
> "The reef consists of dark-blue siliceous slate, crossed by a network of quartz-veins, which gives it a brecciated appearance. A granitic dyke accompanies the reef, and generally divides it in two. Both the dyke and the reef vary in thickness, thus in the Eleanora Company's claim the hanging wall reef is from 6 to 18 inches thick, the dyke from 1 to 5 feet, and the footwall reef from 1 to 4 feet.
>
> "Oxide and sulphide of antimony (stibnite) occur in irregular bunches, and also fairly disseminated through the reefs, but they are absent in places. Gold is sometimes plainly visible in the quartz.

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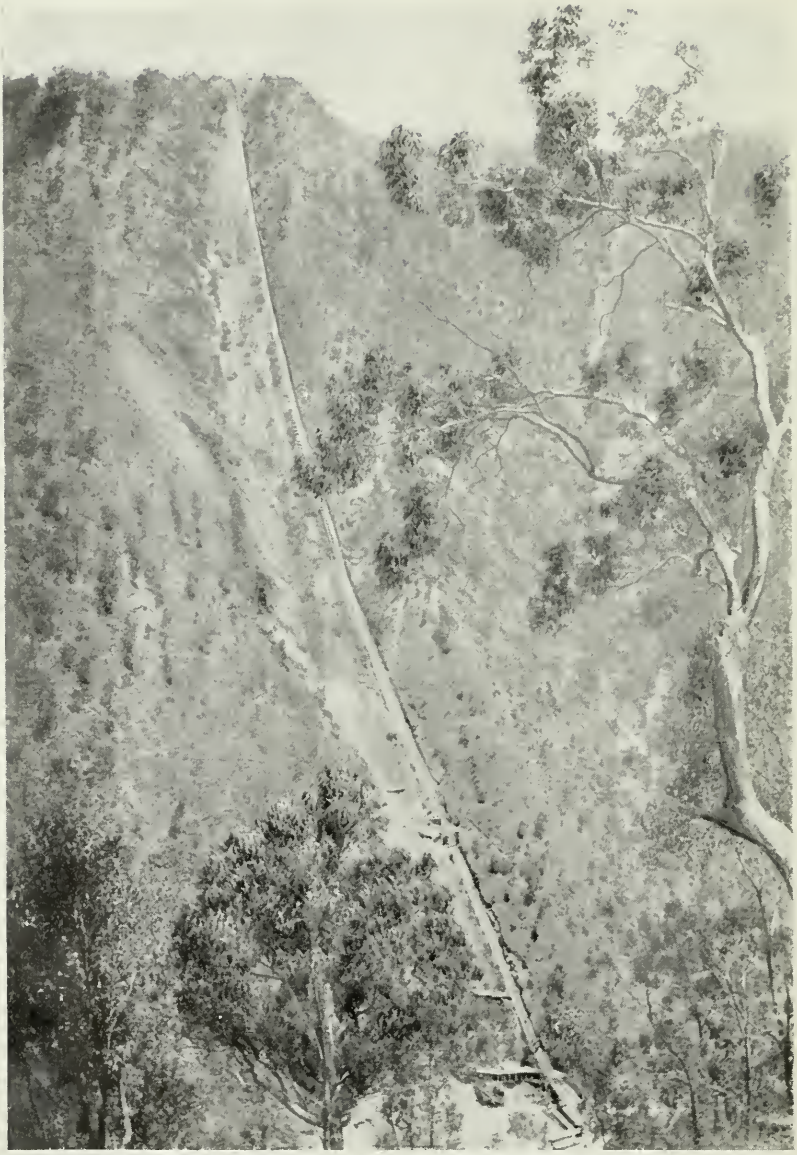
* Ann. Rept. Dept. Mines, 1880, p. 139. † *Ibid*, 1883, p. 26.

Baker's Creek Gorge, looking South from Campbell's Spur.



Sunlight Tramway, seen from the Cooney Tunnel.

". . . The other antimony reefs, one of which occurs at the bottom of the valley at a level about 1,500 feet below the Eleanora Mine, are also stated to be auriferous, but they have only been worked for antimony.

"It is questionable whether the reefs will pay to work for antimony alone, on account of the cost of transit of the ore or metal to the shipping ports of Newcastle or Grafton, but there is little doubt that they deserve special attention on account of their auriferous character."

Hillgrove Mining District—including Gara Falls—has, so far, been the most important antimony producer in the State, though its importance in that respect shortly became completely overshadowed by its gold-production.

The history of the field has been briefly epitomised by E. C. Andrews, B.A., F.G.S., Geological Surveyor, in the following terms*:—

"Havershed (Evershead.—J.E.C.) Brothers and Thomas led the way in 1877 by finding an antimony lode quite close to, and south of, the present Hopetown Reefs. A parcel of 4 tons 17 cwt. was obtained by them from the outcrop, carted to Grafton, and thence despatched to England; £17 15s. was paid for this consignment. Negotiations were then entered into by this party with Hudson & Co., of Sydney, for the purpose of erecting antimony smelting works.

"About the same time, Campbell Brothers mined for antimony on the spur now named after them, and lying a little north and west of Baker's Creek battery. Moore, Speare, and McBean followed by taking up an 80-acre block on the southern side of this spur, and afterwards took up Portion 58. These portions were taken up under the now obsolete 'mineral conditional purchase' conditions, and worked for antimony. At first the mining was performed by tributors, but the owners found these latter shooting much of the ore down the hill slopes, so as to pick it up at their leisure in the creek below. To prevent this loss to themselves, Moore's party took up an additional portion of 80 acres, known as M.C.P. 110.

"In 1878, Brackin, Daly, and Elliott found a long line of reef containing antimony. This was afterwards worked as the Isabella lode. It was discovered on the Hillgrove side of the gully, whereas the previous finds had occurred on the Metz slope. Another event was the discovery of the Paradise and No. 9 lodes, two antimony reefs which, after keeping company for some distance, diverged from their original course, and struck out nearly at right angles to each other. The continuation of these two lodes were found in the flat country above the gorge, and from them one parcel of 10 tons was extracted.

"Another antimony lode was worked on Brackin's Spur, a prominent landmark near the junction of the Baker's and Four-mile Creeks. This lode turned out some very good ore. Junce and Kerseller, acting for an Armidale syndicate, opened up antimony smelting works near the head of Swamp Creek, and treated the various antimony ores of the field.

"Up to this time there had been no thought of gold, and, even when specks of the precious metal were discovered in the Garibaldi Reef, its significance was not appreciated, owing to the difficulty experienced in

* Mineral Resources, No. 8, 1900, pp. 7, 8.

extracting gold from an antimony admixture. The first speck seen on the field occurred in No. 2 shaft of the Isabella line of reef, now known as the Garibaldi Shaft. Aaron Smith is credited with the observation.

"After the Eleanora and Garibaldi had been worked for some time, the attention of the Companies prospecting them was turned to the winning of gold, and in November, 1881, Mr. G. Smith was appointed by an Armidale syndicate to manage the Garibaldi property. Supposed payable gold was found at the Eleanora, and a party of six from Armidale, exclusive of Brackin, Day, and Elliott (who, as discoverers of the lode, were included), formed a company and took up a gold lease of 20 acres.

" . . . The Garibaldi Reef was still worked for antimony. In 1882 came a revival in the demand for this metal, and a consequent rise in price. In 1882 it brought £7 per ton in Armidale. Hargraves, the owner of Hillgrove station, had been working an antimony claim on the top of the Swamp Creek Falls. This was known as the continuation of the Paradise and No. 9 lodes. In 1885 he leased the claim to tributors, and imposed a royalty of £1 per ton on all the ore won. 141 tons of antimony were taken out of this reef in 1885 and part of 1886. Besides this amount, Hargraves had previously extracted 91 tons. A slump occurring in the price of antimony, the value of the crude ore going down to £4 10s. per ton, the lodes were prospected for gold. From these lodes, at various times, about 2,000 tons of crude antimony have been extracted—500 tons from the top, and 1,500 tons from the creek sides. The ore was carted up the gully at first by bullocks, and afterwards by trams.

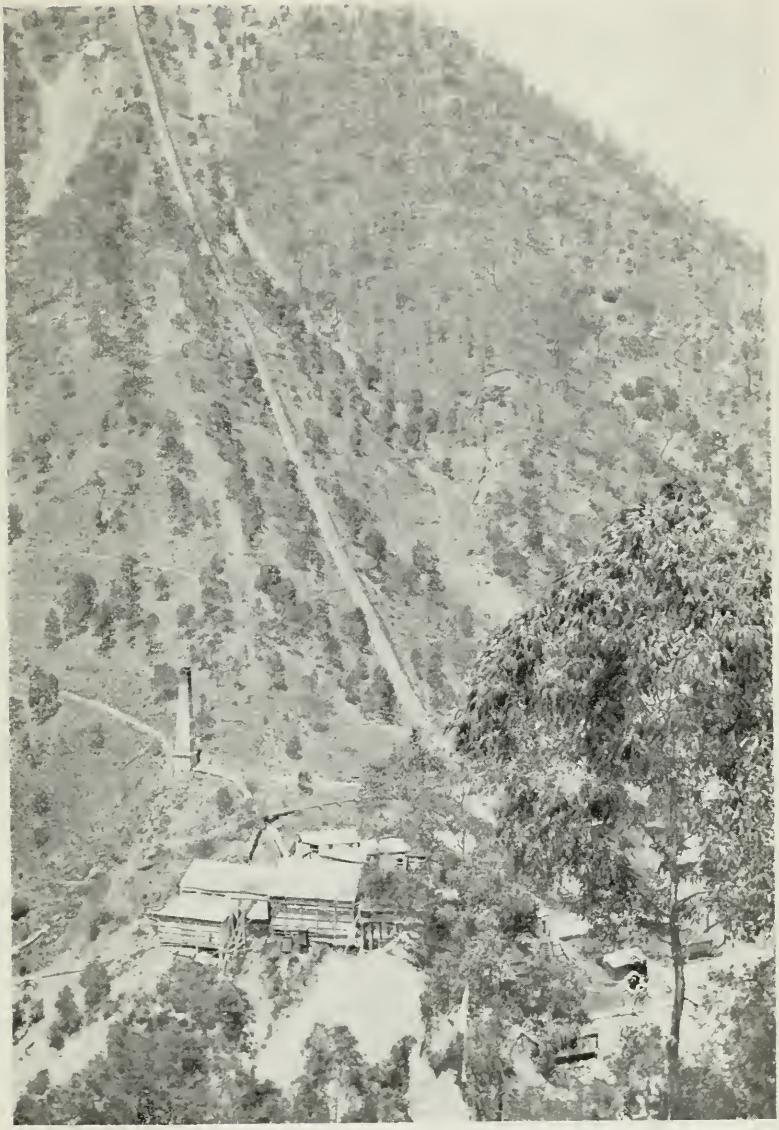
"In the middle of 1886 the Carrington lode, occurring in the granite north of the Eleanora, and worked previously for antimony, was opened up for gold.

"In 1887 came the real opening up of the gold-bearing reefs of the district, when the Little, Big, Middle, and Baalgammon veins were discovered; when the lodes worked by Moore, Speare, and McBean, on the west side of the Baker's Creek gorge, were found to contain gold; and when the Cosmopolitan, Hopetoun, Starlight, and Centennial claims were taken up for gold-mining purposes."

The official records of the individual mines now available are meagre and intermittent. The following items have been abstracted from those published in the Annual Reports of this Department, which are by no means satisfactory :—

Brereton's, M.C.P., 122–124, Hillgrove, parish Metz, county Sandon, on Swamp Creek.—Shown on E. C. Andrews, Geological Map of Hillgrove Goldfield*, and described, under the names of Paradise and No. 9 Antimony Lodes, as follows :—"At the head of Swamp Creek, two large antimony reefs occur, about 60 feet apart, and underlaying slightly towards each other. Traced down the bluffs of the creek head, the Paradise lode is seen to turn off at right-angles and cross the bed of the creek. Close on 2,000 tons of antimony have been extracted from these lines of reef.† Mr. Andrews further records that these two lodes, after keeping company for some distance diverged from their original course, and struck out at nearly right-angles to each other. Their continuations were found in the flat country above the gorge of Swamp Creek, and from there one parcel of 10 tons was extracted.‡

* Mineral Resources No. 8, 1900. † *Ibid.*, p. 42. ‡ *Ibid.*, p. 7.



Baker's Creek Tramway, from Petersen's Shaft.

Slate and Granite Junction, head of Swamp Creek.

Hargrave's Mine embraced the continuation of the Paradise and No 9. lodes. In 1885 he leased the mine to tributors, and imposed a royalty of £1 per ton on all the ore won. 141 tons of antimony were raised during 1885, Hargraves having previously extracted 91 tons. Of the 2,000 town raised, 500 were from the top and 1,500 from the creek sides.*

From Brereton's Mines on these lodes no reliable record is available. In 1880 it is recorded that 75 tons of ore were obtained, chiefly from the surface. In 1883, 250 tons from this mine were sold in Armidale at £7 per ton.

In 1890, 348¼ tons of ore were sold.

In 1906, about fifty men were employed on tribute during the stir caused by great advance in metal values; but the output is not recorded separately.

In 1908, the greater part of 286 tons of ore raised on the field is stated to have come from this mine.

Eleanora Lode, Hillgrove. Of this lode, E. C. Andrews reports :—

> "The Eleanora Reef—as also its southern extension, known as the Garibaldi—runs for the greater part of its length along the flat land at the top of the Baker's Creek gorge. It is the only important line of reef in the area that practically lies above the gully. Towards its northern end it runs diagonally along the face of the gorge till it passes into the coarse granite. Southwards it is continued over the point of the Garibaldi spur, but does not appear to last as far as the greenish granite mass lying in that direction. Its strike is north-west and south-east approximately; and it possesses an underlay of about 1 in 5 towards the north-east. If the Cosmopolitan Reefs are simply continuations of the Eleanora Reef, as appear probable, not only from their line of strike, &c., but quality of stone, as far as antimony is concerned, then this line of reef stands proven over 1½ mile of country. A granite dyke, much altered, follows the lode along the greater part of its course, occupying the central portion of the lode. The country traversed is, for the most part, a slate, altered into a knotted schist. Numerous vughs occur throughout the lode, filled in places with magnificent stibnite crystals. The returns show the reef to be a huge low-grade ore deposit. In places the stone is, with the included dyke, 22 feet wide."†

The antimony output from this mine is incomplete, but from the annual reports of the Department of Mines, the following figures have been obtained :—

1883— 3 tons of antimony, sold locally for £20 14s.

1884— 28 „ „ despatched.

1885— 28 „ „ „ valued at £196.

1888—133 „ „ „ in this year furnaces were being erected for extraction of the antimony before crushing for gold.

1889—38 tons of crude despatched to England. In the treatment of the lodestuff the greater part was roasted in the furnace for extraction of the antimony before being dealt with in the battery. The lode was 8 feet wide in the working levels.

1890—The smelting plant consisted of five furnaces, capable of turning out 50 tons of crude antimony per week.

The antimony, crude, sold this year amounted to 348¼ tons.

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* Mineral Resources No. 8, 1900, p. 8. † *Ibid*, pp. 31-32

In 1891 the separate output of the Eleanora Mine was not recorded, though work was in progress. Mr. Andrews has given a detailed return of the produce of this mine from June, 1892, to December, 1899, viz. :—*

74,560·75 tons of ore treated for—

oz.	dwt	qrs.	
31,477	11	3	of gold.
tons.	**cwt.**	**qr.**	
2,150	14	1	of antimony concentrates.
1,980	6	0	of crude antimony.
85	2	0	of star antimony.
14	10	0	of artificial oxide of antimony.

The calcined antimony concentrates yielded on an average 3 oz. 10 dwt. of gold per ton of a value of £3 10s. per oz.

The antimony oxide brought £16 10s. per ton on the field.

In 1902 the mine closed down.

In 1906.—In the course of gold-mining operations, the New Hillgrove Proprietary Company raised 120 tons of antimony sulphide from the Eleanora lode, valued at £3,500.

Garibaldi Mine, Hillgrove.—Particulars of the output of this mine, which adjoins the Eleanora on the south-eastern extension of that lode, are even more meagre than those of the latter.

The Garibaldi Mine was opened in 1878 for antimony, and in 1881 attention was turned to its gold contents, the first indication of this metal being found in this section.

Mr. Andrews† states, in connection with the Garibaldi property, that—

"This line of reef is the south-east extension of the Eleanora or Isabella line of reef. As with the Eleanora, it was first worked for antimony and afterwards for gold.

"In places, two reefs, or two branches of one reef, appear to have been worked. These lines are 20 feet apart. Two vertical shafts have been sunk, of which No. 2 shaft is 240 feet deep. From the shafts the lodes have been worked by cross-cutting. There are three levels, viz., the 100, 140, and 240 feet levels.

"The 100-foot level, on one line of reef west of shaft, has been driven 90 feet, and to the east has been taken 100 feet. The direction of this level is 5 degrees south of east.

"The 140-foot level is 190 feet in length, and is almost directly under the 100-foot level. The 240-foot level has been reached by cross-cutting 50 feet from the shaft. According to the plan of the workings, the two reefs met with at surface make into one at the 140-foot level."

The only departmental records of the output of antimony from this mine are the following :—

1900—An experimental shipment of 130 tons of antimony ore was sent to England, assaying 40 per cent. of antimony and 1 oz. of gold per ton.

1906—Ore raised on tribute, hand-dressed, and sold to local buyers, valued at £4,011.

Hillgrove Antimony Company, No. 2 Freehold.—The lode worked in this property was described in 1890, as having a width of 18 inches of quartz and antimony; strike, north-west, with an underlie of 1 in 10.‡

Another lode of similar character occurred south of the above.

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* Mineral Resources No. 8, 1900, pp. 31-32. † *Ibid.*, p. 33. ‡ Ann. Rept. Dept. Mines, 1890, p. 108.

Eleanora Plant and Dam, from the East.

Five hundred tons of antimony ore are reported to have been extracted from this property during the preceding five years. Tenders were accepted in 1890 for erection of furnaces.

In 1894, 20 tons of ore were despatched.

Freehold Estates Syndicate, Hillgrove.—During the antimony "boom" in 1906, the value of antimony won by this syndicate was stated to be £8,760. Some of the ore was smelted in a reverberatory furnace, which brought the percentage of antimony from 35 or 40 to 70 and 72 per cent., in which condition it was shipped.*

Cosmopolitan Gold and Antimony Mine, Hillgrove.—The lodes in this mine were originally taken up for gold in 1887, according to E. C. Andrews.† who described them as follows :—‡

> "This property was originally taken up as the North and South Cosmopolitans. It consists of two reefs trending in a north-west direction, and cut across by an east and west gully, which divides the North from the South Cosmopolitan. The reefs lie wholly in the coarse granite (granitite) of the field, and are held by the miners to be the northern continuation of the Eleanora lode. There seems much to favour this idea, since sighting along the strike of the Eleanora as it makes down the gully, brings the hair-line of the compass in line with the direction of the Cosmopolitan tunnels. The lode, however, has not been proved along the whole of this distance, an unproven patch of several hundred yards in length occurring to the south of the South Cosmopolitan. The talus of the hill slope may simply have obscured any possible outcrop however.
>
> "These lodes were pegged out in the same year as the Baker's Creek Reefs, and, though originally worked for gold, were subsequently exploited for antimony. The workings consist of several tunnels driven into the hill on the reef. These tunnels are 100 feet below each other. The lowest is 70 yards in length, driven in a north-west direction. The one immediately above is some 50 yards long, also driven in a north-west direction. The ore was brought to the tunnel-mouths and carried by tram up the sides of the hill. The underlay is to the north-east.
>
> "The South Cosmopolitan consists of tunnels driven in more than 100 feet into the hill. A heave has thrown one of these reefs 12 feet.
>
> "Many large parcels of antimony have been sent from this mine, one yielding 100 tons of metal.
>
> "From the Old and New Cosmopolitan companies gold was obtained to the value of £31. From the 'Old Cosmopolitan,' £547 worth of antimony was extracted, and from the 'New Cosmopolitan,' £350 worth of the same metal was obtained."

In 1890, the tunnel in the Cosmopolitan Gold and Antimony Mine was reported to be 220 feet in length in a lode 2 to 5 feet wide, consisting of quartz and antimony, carrying a little gold. No. 1 winze was down 120 feet, No 2 40 feet, and No. 3 90 feet.

During this year 130 tons of antimony were shipped to England and there sold at an average of £30 per ton.

Long Point, 4 miles south-east of Hillgrove.—C. S. Wilkinson, in 1889, recorded that Messrs. Becke and party were prospecting an antimony reef which crops out on an eastern face of a steep range. "It pinches out near

* Ann. Rept. Dept. Mines. 1906, p. 56. † Mineral Resources No. 8, 1900, p 8. ‡ *Ibid.*, pp. 33, 34.

the top of the range but widens lower down, and dips north-north-east at 60 degrees in jointed granite. Being associated with an intrusive dyke of granite, like that which accompanies the Eleanora and other auriferous antimony reefs at Hillgrove, this reef should be prospected."*

Sunlight Lodes, Metz, Hillgrove, portions 58 and 109, parish Metz, county Sandon.—E. C. Andrews states that Messrs. Moore, Speare, and McBean took up the above portions in 1877, as mineral conditional purchases, and worked for antimony. At first the mining was performed by tributors. As the latter were shooting much of the ore down the steep slope, an additional block was taken up lower down (M.C.P. 110).†

In 1887 gold was discovered in the Sunlight antimony lodes, which were then worked for gold alone. According to E. C. Andrews,‡ 36,873 oz. of gold were won from the Sunlight Reef from 1892 to the end of 1899; and 19,000 oz. from the West Sunlight between 1894 and 1899, these amounts being exclusive of the gold contained in the concentrates, and of the gold won prior to the dates mentioned.

On portion 58 scheelite was subsequently discovered and worked.§

In the Sunlight section, one reef was worked, and two in the West Sunlight, down to near the 430-feet level, where they joined into one.

E. C. Andrews‖ describes the Sunlight Reef as striking 25 degrees north of west: and "running fairly parallel to the outcrop of the latest granitic intrusion. The country is of slate and schist, much contorted and broken up by crushings and a series of small faultings. The dip is about 1 in 5 in an easterly direction. The walls are better defined here than in other reefs of the field. Magnificent crystals of stibnite (antimony sulphide) are found in vughs. From the surface to the No. 5 level the exploitation of the mine was carried on by means of short tunnels driven in from the hill sides. As the underlay is toward the creek, and the sides of the gorge are very steep, this method of winning the ore was comparatively easy. . . ."

Most of the reef has been won in the western end down to the 7th leve (800 feet).

The eastern end of the lode has been much faulted, but no trouble has been exercised to pick it up, as the stone is of inferior quality. Still, much of the stone has been extracted as low down as No. 5 level. In all, five shoots of stone are said to exist in the mine, each of which is more or less vertical.

West Sunlight Mine, Metz, Hillgrove.—In this section Mr. Andrews states:—

> "Two reefs were worked, the Magazine and the West Sunlight or Main Reef. The strike of the reef at the boundary between the Sunlight and West Sunlight properties is 20 degrees north of west, and the lode has been proved for 800 feet in this direction. Traces of it exist in the rough country to the north-west, but no payable prospects have been obtained.¶ . . . . The Magazine and Main Reefs were worked simultaneously from a main shaft, crosscuts being driven from the main line to work the Magazine Reef. At the 430-foot level the two reefs made into one. In all, ten levels have been driven.**

During 1906 the West Sunlight Mine was worked for antimony on tribute. 481 tons produced were valued at £10,000. A smelting furnace was in course of erection at the end of the year.††

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* Ann. Rept. Dept Mines, 1889, p. 205. † Mineral Resources, No. 8, 1900, p. 7. ‡ *Ibid.*, p. 9.
§ Mineral Resources, No. 15, 1911, by J. E. Carne. ‖ Mineral Resources, No. 8, 1900, pp. 34, 35.
¶ *Ibid.*, p. 36. ** *Ibid.*, p. 38. †† Ann. Rept., Dept. of Mines, 1906, p. 56.

Horse-shoe Bend Lode, M.L. 1, parish Carnham, county Drake, close to Clarence River. Discovered by J. F. Adams about 1890. Sunk upon by T. Bassetti for about 50 feet in 1907, and 4 tons of dressed ore despatched, averaging 50 per cent. metallic antimony. The lode maintained a thickness of 9 inches to the level mentioned.

Horse-shoe Bend, Clarence River.—In 1890 discovery of antimony was reported at Horse-shoe Bend, on west bank of Clarence River, about 3 miles south-east of Lionsville.

J. F. Adams shortly after opened a parallel lode about half a mile further south, and later several other lodes.

Hunt's Creek, Peelwood.—A sample of sulphide and oxide from this locality was assayed in 1885 for 23·44 per cent. of antimony.

Kelly's Lode, M.L. 5, parish Carnham, county Drake.—Discovered by M. R. Kelly about 1890, shortly after J. F. Adams' discovery of antimony at Horse-shoe Bend, Clarence River.

Opened by tunnel, and about 10 tons of dressed ore despatched.

Lionsville District.—Antimony was first discovered in this district in 1875, when the Pucka lode was located in portion 76, parish Yulgilbar, county Drake.

In 1876, a 20-acre mineral lease was applied for by H. Maurice, on the 28th December, 1876, which was surveyed as M.L. 38, parish Carnham, county Drake, on 4th June, 1877, 6 tons of dressed ore being raised from it in one week by two men.

In 1890, several lodes were opened up in the district; an old lease was taken up by T. G. Beatty, under the name of "Burnt Down." From this lode 60 or 70 tons of ore are reported to have been extracted, which, however, did not pay, owing to high rate of carriage and low ore value.

In 1890, 3½ tons of dressed ore were obtained from this lode.

J. F. Adams opened a parallel lode in the same year about 40 chains south, and extracted 2 tons of ore.

In this year also Mr. Bryce discovered a well-defined lode near the junction of Collum Collum Creek and Washpool Creek, from which 3½ tons were obtained.

Kelly and party also despatched 5 tons from Horse-shoe Bend, near Burnt Down.

In 1906 a small parcel of ore was despatched from this district, probably from the Pucka lode.

Lucknow, New Reform, now Wentworth, Gold Mine, 3 miles from Orange.—Metallic antimony occurred with calcite and rich gold, at the junction of serpentine and diorite, in this mine.* A sample submitted to analysis yielded—

Carbonate of lime	59·200
Metallic antimony	38·750
,, gold	·026
,, silver	·005
Oxide of iron	·750
Silica	·350
Sulphur	·570
Magnesia, loss, &c.	·349
	100·000

* Stibnite occasionally also, according to E. F. Pittman (Min. Resources N.S. Wales, 1901, p. 246).

Lunatic Reefs, parish Jenny Lind, county Buller.—Antimony was first reported from the locality in 1876. In 1877 about 47 tons of ore were despatched to Sydney, the lode then being worked by the Hercules Smelting Company, of Sydney.

In 1878 the company raised 6 tons of ore, when R. Horton entered into possession and raised a further 4 tons. The lode was worked to a slight extent in 1879. No further records are available until 1890, when 26 tons were raised.

Lunatic Antimony Lodes, in M.C.P.'s 1, 2, 3, and 72, parish Antimony, county Buller, 7 miles north of Drake.—Examined by E. C. Saint-Smith, Field Assistant, in 1910, who reported that a large quantity of antimony was obtained from near the north-east corner of M.C.P. 2 by Throgmorton. It occurred as an oxidised surface "blow." At a depth of 16 feet the country became hard and the vein narrow. The ore won was from an open cut or trench, and carried up to 15 dwt. of gold to the ton. A little antimony is distributed in parish Antimony and down to parish Emu, but not in payable quantities. Throgmorton's output was shipped to London during the antimony boom.

A little antimony occurs in most of the Lunatic Reefs in G.L.'s 15, 102, 169, and 190, in quartz veins traversing slate, striking north and south vertical.

Macdonald River.—Antimony reported at the head of this river.

Macksville Division, Nambucca River.—In 1891, 49 tons 14 cwt. of ore were raised from the Real McKay Mine, which realised £806 12s. 8d.

Manilla.—In 1907, Messrs. Smith and Parkinson forwarded antimony ore assaying 58·38 per cent. to the Balmain Smelting Works from between Barraba and Cobbadah.

Marulan.—Antimony ore from the Carrington Mine, near Marulan, associated with galena and quartz, was assayed in 1886 for 16·17 per cent. of antimony, and yielded gold at the rate of 2 oz. 17 dwt., and silver 164 oz. 3 dwt. per ton; lead, 22·27 per cent.

Meglo, Tuena district.—The recently discovered silver-lead ores of this locality evidently have antimony as an associate. A sample from the Bonanza Mine, assayed in the departmental laboratory in September, 1911, yielded the following results :—

11-2,303—Gossan :—
Gold, 4 dwt. 8 gr.
Silver, 16 oz. 5 dwt. 14 gr. } per ton.
Lead, 25·4 per cent.
Antimony, 10·34 per cent.

Mosquito Creek, about half a mile up Clarence River, above junction, at Paddy's Flat, in M.L.'s 40 and 41, parish Ellerslie, county Buller. A fairly large quartz vein, with a small amount of antimony and arsenic. Strike, north-west. Taken up by Flood and party about 1888. Tunnel driven for 40 feet along lode, commencing from bank of river. A small quantity of unmarketable ore obtained.

Mount Mitchell, near Oban.—The Rev. W. B. Clarke, in 1853, recorded that :—

> "Of metals besides gold, I have met with sulphuret of antimony as near Mount Mitchell and in the Booroolong Run, as well as in the neighbourhood of Gara."*

* Parliamentary Papers, Rept. No. VIII, 7th May, 1853, p. 5.

Neil's Creek, Moonan Flat.—A sample of antimony sulphide in quartz from a depth of 20 feet, in a gold lease at Neil's Creek, was forwarded to the Department in August, 1906, by J. C. Ross, which assayed 37 per cent. of antimony.

Nerriga.—A sample, stated to come from Nerriga, was assayed in 1885 for 22·43 per cent. of antimony. It consisted of quartz and stibnite.

Niangla, at Paradise, 8 miles south of Niangla, parish Scott, county Parry.—G. A. Stonier reported a discovery of antimony at Paradise in 1892.

North Sydney.—The Rev. W. B. Clarke recorded finding a rolled specimen, 3 lb. weight, of stibnite, in the superficial gravel on an unfrequented hill on the North Shore of Sydney Harbour.* [Probably a carried specimen, dropped by an aboriginal.—J.E.C.]

Nullamanna, 16 miles north of Inverell, parish Nullamanna, county Arrawatta, on J. McElroy's private land. Inspector Carthew examined the site in 1902 in connection with an application for aid from the Prospecting Vote, and described the occurrence as an antimony and silver lode striking east and west in quartzite. Dip, north. Opened to 20 feet by shaft. Aided to continue to 120 feet. At 45 feet the altered sedimentary rock in which the lode occurs was very hard; at 96 feet the lode was struck. At 140 feet the prospects were poor, leading to abandonment.

Nundle, Peel River.—In 1854, F. Odernheimer exhibited "sulphuret of antimony, related to siliceous and limestone breccia," from about 3 miles west of the Peel River and 12 miles north of Hanging Rock.†

In 1875, an antimony lode, striking north and south, was recorded at Nundle, a little superficial proving being done.‡

In 1876, the Mining Registrar reported that the lode varied in thickness, so far as opened, to a depth of 15 feet and a length of 40 feet. The thickest part of solid antimony sulphide was 4 inches, which pinched to nothing in other parts.

In 1877, two men were at work; the deepest shaft had reached 60 feet; the lode varying from ½ inch to 5 inches in thickness; ore not very pure.

In 1890, Woodley and party held two 40-acre leases. In the lower lease the lode was reported to be from 12 to 18 inches wide, and to contain some 65 per cent. ore. In the upper lease equally good ore was reported, but narrower. The latter was worked by shaft and level.

In 1907, W. Paul forwarded 4 tons of 61·14 per cent. ore to the Balmain Smelting Works, the "boom" in value having directed attention to the deposit.

In 1888, D. A. Porter described a vein of antimony ore:—

> "Near the old flour-mill on Oakenvale Creek, and extending thence into Happy Valley. The vein is small, and very irregular in width, from 2 to 12 inches, and the ore appears to be of inferior quality. The vein is in hard, jointed, argillaceous slates, which are much tilted."

In 1910, Mr. M. Morrison, Senior Field Assistant, reported on the antimony occurrences near Nundle, as follows:—

> "The occurrence of antimony at Nundle has been known for at least thirty-four years. During that time, a little mining has from time to time been carried out, and small parcels of ore obtained.

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* Min. Prod., 1882, p. 100. † Cat. of Nat. and Indust. Products of N. S. Wales, exhibited by the Paris International Exhibition Commissioners in the Australian Museum, Nov. 1854, p. 54. ‡ Ann. Rept. Dept. Mines, 1875, p. 96. § Proc. R. Soc. N. S. Wales, XXII, 1888, p. 80.

"Some twenty years ago several 40-acre mineral leases were secured within a mile of Nundle, and mining carried out; but I understand that only a few small parcels of ore were sent away.

"No mining was being done for antimony at the time of my inspection, and, in consequence, I was not able to enter any of the workings.

"At least two distinct lines of reef have been worked. They occur in slate country, and strike about north 20 degrees west, and apparently underlay to the north-east. I was informed that the reefs vary in thickness from a few inches to 18 inches.

"During the year 1906 there was a slight revival in antimony mining, due, no doubt, to the increased market value of the ore.

"Mr. J. Fogarty, of Nundle, who has probably purchased most of the antimony ore raised locally within the past four years, informed me that during that time only about 15 tons passed through his hands. Messrs. Kelly and party supplied 12 tons, Paul and Son 1 ton, and Rackman and Son ½ ton, and several small parcels of a cwt. or two were brought in by different prospectors. The average price paid for the ore was £14 per ton. Messrs. Kelly and party worked a reef in M.L. 3, about ½ mile north-east of Nundle, where a shaft is sunk to a depth of 80 feet.

"Paul and Son prospected a reef at Happy Valley, and sank a shaft to a depth of 40 feet. A considerable amount of work has been done on the reef by tunnelling and sinking. It is proved for a length of 10 chains.

"Rackman and Son sank a shaft on a reef on the bank of Oakenville Creek, about 1½ mile from Nundle. The shaft is now full of water."

Paradise. (See Niangla.)

Peckitt's Hill. (See Bellingen River.)

Pennyweight Flat, Nundle.—Inspector Milne reported in 1906 a promising discovery of antimony and scheelite at Pennyweight Flat; and that some small parcels of ore were despatched. (See Nundle.)

Penshurst Estate, Paterson River.—In 1861, A. K. Holden exhibited antimony ore from Penshurst Estate and other parts of the Paterson River District.* The exhibit was displayed in the London International Exhibition of 1862.

Pretty Gully.—In 1877 a ton of antimony ore was despatched from Ball and Smith's Mine at Pretty Gully, near Drake, from a lode 1 foot wide. 20 acres taken up for antimony mining.

Pucka Mine, portion 76, parish Yulgilbar, county Drake.—Discovered probably in 1877, for in the following year arrangements were made to work the deposit. The lode occurs in private land secured by Smith Brothers, of Gordon Brook, under Volunteer Land Order.

In 1879, work was in progress. In 1880, Mr. E. F. Pittman, visited the site, and recorded that—

"At Pucka (Yulgilbah Station), and on the South River Range, are fair lodes of antimony sulphide (stibnite). These deposits will be well worth prospecting in the future."†

In 1891 a few tons of ore was raised, and 24 tons in 1892, valued at £288.

In July, 1907, the Writer visited the site, when Mr. T. Bassetti, of Lionsville, was engaged reopening the lode; and, in so doing, had struck a small patch of wolfram, associated with stibnite.

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* Cat. Nat. and Indust. Prod. N.S. Wales, Sydney, 1861, p. 39.
† Ann. Rept. Dept. Mines, 1880, p. 245.

Two lodes occur, striking north 65 degrees east, about 12 feet apart. The original workings are situated about 15 chains on the north-eastern strike from the more recent provings. Judged from the waste-heaps the lode at this point consisted of massive quartz, with bunches of stibnite.

Mr. Bassetti sank 26 feet, the antimony lode varying from a few inches to 18 inches in thickness, and carried sulphide and oxide of antimony. Quartz predominates to the north-east. Twelve tons of 48 per cent. ore were despatched in 1907.

Puddledock (*near*) county Sandon, Armidale District.—Siliceous antimonite was assayed from this locality in 1906 for a yield of 37 per cent. of antimony.

Pyramul.—In 1875 stibnite was assayed from Pyramul, described as in massive form, showing well-developed striated cleavage planes; exterior coated with oxide, the assay result being:

Metallic antimony, 67·74 per cent.
Gold and silver, traces.

Pulganbar.—Antimonite in small quantity associated with the mercurial ores of this locality, portion 132, parish Pulganbar, county Drake.

Razorback Gold and Antimony Lode, parish Walberton, county Roxburgh. In 1881 the first lease was applied for (M.L. 30) by Samuel Mannell, and surveyed 29th August, 1881.

In 1882, a sample from this lode was assayed for a yield of 30·42 per cent.

In 1884, in Hedgeley's lease, formerly Warwick's, a depth of 100 feet was reached. At 70 feet the lode was reported as 4 to 6 inches wide, and 2 feet at 100 feet. Fifteen tons of ore were raised this year.

In 1886 the site was examined by C. S. Wilkinson, who reported—

"At Razorback an auriferous quartz reef, containing iron pyrites and sulphide of antimony, traverses black slate country; it occurs like the Eleanora Mine, near Armidale, with a trap dyke, and varies in thickness up to 3 ft. 6 in., dipping west 25 degrees south, at an angle of 1 in 6. As it follows the trap dyke, it will probably be permanent in depth. It has not been traced continuously, but at intervals for a distance of about 25 chains, and a considerable amount of work has for some years past been done in working it for gold. Ten shafts have been sunk along the line of reef, the deepest being about 130 feet; but Mr. Oppenheimer, who now holds the greater portion of the line of reef, is having a shaft put down to 160 feet, with the expectation of striking the shoot of gold-bearing stone said to have been worked in No. 5 shaft.

"A mixed sample of reef stone from the 130 feet level, where the reef is 18 inches thick, consisting of quartz, calcite, black slate, pyrites, and sulphide of antimony, gave, on assay, at the rate of gold, 3 dwt. per ton, and metallic antimony, 4·1 per cent.; but this, not being a bulk sample, cannot be considered as an average test, as the ore is irregularly distributed through the reef, causing portions of it to be poorer or richer than others. The gold is sometimes visible in the antimony, and the stone containing antimony is sorted and bagged up, and forwarded to Europe for treatment. Mr. Oppenheimer informed me that a parcel of 96 bags, weighing 5 tons, was culled from about 20 tons, and that two average bulk assays of it gave at the rate of 5 oz. and 7 oz. per ton, and the parcel was sold at the rate of 6 oz. per ton; it contained about 45 per cent. of antimony. The balance of 15 tons is said to have yielded about 1 oz. of gold per ton. Mr. Oppenheimer states that he despatched from the mine 2,278 bags of ore, weighing 116 tons 16 cwt., which

realised £1,881. . . . O'Brien and party are sinking on their claim, which adjoins Oppenheimer's on the south, one of their shafts being 75 feet deep, on similar reef-stone, containing antimony ore.*

Work was suspended in 1887.

In February, 1902, the mine was examined by the Writer, and the following report furnished :—

REPORT ON THE RAZORBACK GOLD AND ANTIMONY MINE.

17 February, 1902.

I HAVE the honor to report having inspected portion 16, parish Walberton, county Roxburgh, also the Razorback Gold and Antimony Mine immediately adjoining on the north, with a view of ascertaining, if possible, which of the two metals—gold or antimony—is likely to prove of preponderating value in the extension of the metalliferous vein into portion 16.

Unfortunately the principal shaft on portion 16, sunk some two years ago to cut the Razorback vein at the boundary, is not now open to inspection, nor yet any of the recent prospecting shafts and trenches, with the exception of a couple of shallow shafts in which no defined veins are visible. Judging, however, from the tips, and the practical absence of veinstuff therein, in each case, nothing of value has, apparently, yet been discovered ; certainly nothing is at present discernible. Mr. O'Brien's declarations in these papers regarding the results of the earlier operations bear out this statement.

The shafts and trenches sunk and cut by the Razorback Company under the permit have been filled up with the exceptions mentioned, in accordance with the Mine Manager's stated belief that such was obligatory under the permit.

In the tip-material of some of the provings, thin fragments of quartz are visible, but no sign of antimony. Colours of gold are reported obtainable in some portions of the rubble. The majority of the shafts have been sunk in country rock, the whereabouts of the vein extension not having been discovered.

Under the circumstances set out, it would appear that the merits of the case must, to a large extent, be determined by the conditions which prevail in the Razorback Mine, which apparently embraces the maximum development of the ore-shoot. The question of relative values of associated metals must also be governed by the actual provings in the letter, which form a valuable index to what may be anticipated under the most favourable conditions of development in the southern extension of the reef into portion 16.

A short account of the provings in the Razorback Mine, therefore, becomes imperative. The working shaft, situated about 204 feet from the north boundary of portion 16, has been sunk 332 feet on the reef, which strikes nearly north and south, and underlays to the west at an angle of about 60 degrees. One hundred feet of the sinking and some driving was aided from the Prospecting Vote—*vide* 96-4,207.

Three main levels have been driven—No. 1 at 150 feet, No. 2 at 252 feet, and No. 3 at 332 feet (manager's measurements).

The vein-channel varies from 1 to 4 or 5 feet in places, averaging perhaps 2 feet 6 inches to 3 feet. The antimony sulphide seldom occurs solid for a greater thickness than 3 inches, though thicker bunches are reported. The best antimony shoot on that portion of the lode carrying the largest proportion of it, is said to measure 24 feet horizontally, extending in about equal proportion on either side of the shaft. Lower grade antimony ore—from 2 to 4 per cent.—extends for about 100 feet south, whilst a small proportion of the metal permeates all the vein stuff.

To the north, in the two lower levels (the upper not being examined), the vein becomes thin, troubled, and split, and its contents low. To the south the conditions of occurrence are more favourable.

The footwall of the vein is well defined, and, with the soft dig upon it, gives evidence of permanence. The vein-channel is filled with broken and crushed country, quartz, and calcite. The richer portions lie along the footwall. The longest and best developed occur along the southern portion of the strike towards Portion 16.

From the face in No. 3 level, 175 feet south from the shaft (about 29 feet from portion 16), a sample was taken to ascertain approximate value. The following results were obtained in the Departmental Laboratory :—

Assay No. 02-331—	
Gold	8 dwt. 17 grs. per ton.
Silver	2 dwt. 4 grs. per ton.
Antimony	0·59 per cent.

* Ann. Rept. Dept. Mines. 1886, p. 138.

From the face in No. 2 level, at 112 feet south from the shaft and 92 feet from portion 16, a selected sample yielded :—

Assay No. 02-332—

Gold	11 dwt. 23 grs. per ton.
Silver	3 dwt. 6 grs. per ton.
Antimony	1·16 per cent.

About 12 feet from this face a winze is being sunk on a bunch of antimony sulphide. From the solid ore, about 2 inches to 3 inches in thickness, a sample was selected to ascertain gold contents, with the following results :—

Assay No. 02-334—

Gold	10 dwt. 21 grs. per ton.
Silver	3 dwt. 6 grs. per ton.
Antimony	63·48 per cent.

From the same spot a sample of quartz and antimony sulphide was selected to represent "seconds" in quality, which yielded :—

Assay No. 02-333—

Gold	8 dwt. 17 grs. per ton.
Silver	2 dwt. 4 grs, per ton.
Antimony	19·10 per cent.

From these results it would appear that the gold contents are at present remarkably constant in the southern portion of the lower levels. As bulk tests and previous assays from higher levels established a higher connection between the antimony and gold, check assays were made of samples Nos. 333 and 334 without disturbing the previous results.

Perhaps the most reliable idea of the average contents of the vein from all levels worked by the Razorback Company may be obtained from the following assay results of bulk consignments, properly sampled by the St. Helen's Smelting Works, near Liverpool, England, which have been placed at my disposal by Mr. Kennedy, representative of the Razorback Company.

I preface these results with the manager's statement that, during the latter company's operations since October, 1900, about 28 tons (estimated) of first antimony ore only have been raised, notwithstanding the large amount of sinking and driving performed.

150 bags "Firsts," 6 tons, yield :—

Antimony	28·58 per cent.
Gold	2 oz. 12 dwt. 2 grs. per ton.

75 bags "Seconds," 3 tons 2 cwt., yield :—

Antimony	14·83 per cent.
Gold	1 oz. 16 dwt. 15 grs. per ton.

241 bags "Thirds," 10 tons, yield :—

Antimony	3·46 per cent.
Gold	7 dwt. 10 grs. per ton.

Another consignment from definite positions in the workings gave the following returns, according to the same authority :—

No. 1, 57 bags from shaft at 251 feet level, yield :—

Antimony	22·84 per cent.
Gold	1 oz. 16 dwt. 7 gr. per ton.

No. 2, 68 bags from 251 feet level, 25 feet south of shaft, yield :—

Antimony	24·75 per cent.
Gold	1 oz. 6 dwt. 2 grs. per ton.

No. 3, 65 bags from 251 feet level north from shaft, yield :—

Antimony	2·27 per cent.
Gold	2 dwt. 7 grs. per ton.

Accepting these returns as authentic—and there is no reason to doubt their *bona-fides*—the intimate association of the gold and antimony is clearly established.

The crucial question then remaining to be answered is the relative values of the metals in the vein. As the latter belong to different owners—the Crown and the owners of the land—their values should be determined independently of each other.

Discarding the returns from the northern workings as having little or no bearing on the case, the gold returns from this mine—considered apart from the antimony—are certainly in payable proportion. Into the deleterious effects of antimony on gold amalgamation, and the losses thereby entailed, it is needless to enter, as the Crown is not concerned in this aspect of the question.

Considered solely as an antimony mine, there can be but one conclusion arrived at, viz., that it would not pay to work, the antimony forming but a small proportion of the vein, and the highest grade selected ore (less than 30 per cent.) falling far short of the marketable minimum, which usually stands at 50 per cent.

Taking all phases of the question into consideration, I am of opinion that the value of the gold in the Razorback Mine exceeds the value of the antimony; and as the extension of the vein into portion 16 is unlikely to alter the conditions of occurrence (save, in my opinion, to increase the difference in favour of the gold), I think the decision *in re* portion 16 must be governed by the facts established in the Razorback Mine.

Rockwell Antimony Mine, on Cudgegong River, about 3 miles from Rylestone, in private land.—Lode discovered in 1881, cut at depth of 20 feet, width 2 to 4 feet. The Rockwell Antimony and Gold Mining Company being floated to work it; capital, 11,000 shares at £1 each; area, 40 acres.

In 1883 several shafts had been sunk, the greatest depth reached being 100 feet. Lode reported 8 to 12 inches wide; 20 tons of ore at grass; £800 expended.

In 1884 several assays were made, the stibnite ore yielding 33·38 per cent., the cervantite ore yielding 61·40 per cent.

Sharpening-stone Creek, near Yass, is reported as an antimony locality.*

Springthorpe's Lode, M.L. 7, parish Carnham, county Drake.—Discovered and opened by P. Marcolino in the seventies. Springthorpe held the lode for some years, but despatched no ore. T. Bassetti opened three parallel lodes close by at a later date, and despatched 3 tons of dressed ore. These lodes ranged from 4 to 6 inches in thickness.

South Coast Districts.—In 1907, H. Field forwarded 3 tons 2 cwt. of ore, assaying 25·7 per cent. of antimony, from the South Coast to the Balmain Smelting Works, but the exact location cannot be ascertained.

South River Range. (See "Pucka.")

Stockman's Lode, between M.L. 5 and Lionsville, on top of Tungbung Range, parish Carnham, county Drake. Average thickness about 4 inches. Opened to about 30 feet in depth. No ore despatched.

Sugar-loaf Hill, on Spring Creek, a tributary of the Gwydir River.—Antimony reported here.

Terrible Billy, M.L.'s 1 and 2, parish Scott, county Parry, about 3 miles south-south-west from Terrible Billy.—Discovered about 1888. Strike north-east. Little work done to prove the extent of the antimony-bearing lode in these leases.

Top Horse-shoe Bend, Clarence River, in portion 21, parish Keybarbin, county Drake, opposite junction of Washpool Creek.—Antimony discovered in this portion by H. Towns about 1906, blocks of oxide and sulphide being exposed in a trench, the ore having a width of 3 to 4 inches.

Ungarie.—From Ungarie, in the Wyalong district, quartz, with tinstone, arsenic, and stibnite, was assayed in 1903 for a return of 14·46 per cent. antimony, and gold at the rate of 2 oz. 14 dwt. 10 grs., and silver 1 oz. 8 dwt. 7 grs. per ton.

Upper Meroo River.—S. Stutchbury, Geological Surveyor, in 1852 reported:—

> "Near to Campbell's Creek, on the road to Suttor's old station to Nuggety Gully, close to some gold workings recently discovered, there occur, scattered about, masses of decomposed quartz, rich in sulphuret of antimony, the variety called Jamesonite, with yellow oxide of antimony. I did not find the lode, but there can be no doubt but it

* Min. Prod. N.S. Wales, 1882, p. 100.

may be found in considerable quantities. Independent of its commercial values, it is interesting from its being frequently an accompanying metal with gold." *

Uralla.—A sample received from near Uralla in 1880 was assayed for a return of 56·4 per cent. of antimony.

Walcha, 14 miles from ; and half a mile south-west of Walcha, or Orundumby Station.—Antimony ore was discovered in this locality in 1880, and three 20-acre leases were applied for.

In 1884, a sample from between Walcha and Bendemeer was assayed for a return of 40·2 per cent. of antimony, with a trace of gold, and silver at the rate of 24 oz. 18 dwt. per ton.

Wangwauk, M.L. 1, 20 acres, parish Coolongolook, county Gloucester.—Applied for in 1879 by D. Cameron ; surveyed 14th July, 1880.

In 1886 a sample of stibnite in quartz from this site assayed 31·29 per cent. of antimony.

In 1890 the lode was being reopened. In that year the Warden reported that the gold and antimony mines, 5 miles north of Coolongolook, were opened by two shafts to depths of 24 and 54 feet, some fair antimony showing. Lode, 2 feet thick. Strike north and south, dip west, in slate country.

Williams River.—A sample from this river, at a point 20 miles north of Dungog, was assayed in 1884 for a return of 52·64 per cent. of antimony, gold 4 dwt., and silver 3 dwt. 5 grs. per ton.

Wollomombi, portions 1 and 17, parish Wollomombi, county Sandon, 10 miles north-east of Hillgrove.—Stibnite in quartz from here was assayed in 1906 for 28 per cent. of antimony.

Yarrowyck.—Between Armidale and Bundarra, parish Barlow, county Hardinge, on J. W. Bright's land.—Prospecting for antimony was in progress in 1906. In 1907 the site was visited by Inspector James, in connection with an application for aid from the Prospecting Vote, who described the occurrence as a reef in granite, carrying gold, silver, and antimony. Two shafts had been sunk 30 and 42 feet, respectively, and shallow holes along the line of reef. Aid was granted to continue the 42 feet shaft a further 25 feet. At 54 feet the sinking was very hard, the lode-stuff being quartz and stibnite ; it was shortly afterwards abandoned.

In 1907 a small parcel of ore was raised during the " boom."

* Parliamentary Papers, Rept. dated 1st Oct., 1852.

VIII.—GEOLOGICAL OCCURRENCE OF ANTIMONY ORES.

C. Y. Wang* has attempted an epitome of the geological occurrence of antimony in various parts of the world, from which the following notes have been extracted, and to which are added the New South Wales occurrences :—

Country.	Geological Formation.
Germany	In crystalline schists. Silurian. Devonian. Culm.
Hungary	... Granite.
Bohemia	Most of the lodes are associated with dykes—mostly lamprophyre, but some porphyry—cutting through an intrusive granite stock.
Servia	Limestone and slates, cut by biotite trachytes, and less often by hornblende andesites. The eruptive rocks occurring as dykes, sheets, and stocks.
France...	Quartz veins in granite. In gneiss and mica schists.
Italy	Eocene shales and Miocene limestones, Rhætic limestone, Permian slates, and mica schists.
Spain	... Metamorphic schists and shales.
Portugal	... Junction of palæozoic rocks and granite.
Algiers...	... Clays and limestone of Neocomian age.
Sweden	... Primitive formations.
North America ...	Trenton shales (Arkansas). Sandstones and conglomerates (Utah). Clay shales and sandstones of Cambro-Silurian age (New Brunswick, Canada).
Japan	Schists and other palæozoic rocks. (In limestone also. The Mineral Industry, XIX, 1900, p. 40.)
Borneo...	... Limestone and slate.
New South Wales, Australia	The principal lodes occur near junction of slate and granite (Hillgrove). Permo-Carboniferous or Carboniferous sandstones and claystones (Macleay River). Altered sandstones and slates, and schistose rocks, traversed by granitic dykes (Nambucca and Bellingen Rivers). Devonian slates and sandstones. Gneissic granite.

* Antimony, its Chemistry, Metallurgy, Uses, &c., 1909, pp. 46–57.

World's Production of Antimony.

F. T. Havard states** that :—

"Amongst producers of the actual metal, China easily leads, its exports of regulus and metal, in 1908, amounting to 9,356 metric tons, or more than twice the combined production of all other countries. The principal mines are situated in the province of Hunan, north-west of T'ung-t'ing Lake, I-yang being the chief centre. The ore is hand-picked at the mines, and is brought by boat to Changsha, the centre of the antimony trade in China. Here the ore is liquated, and the regulus sent to Hankow, to be either refined or exported in the crude state. During 1908 there was a notable decrease in the export of ore, and a corresponding increase in the export of crude antimony.

. . . "Most of the regulus exported has hitherto gone to France, Germany, and the Netherlands; but in 1908 exports to the United States, which had previously been very small, increased until they exceeded those of any other country.

"After China, France is next in importance as a producer of antimony. Her supplies of raw ore are maintained by local mines, and in particular by those of the Auvergne Mountains, shipments from Australia and China. England levies toll on China, Australia, Japan, and Canada for antimony ore. Italy mines and smelts ore from its own deposits, while Germany is in a similar position to the United States, producing much hard lead and but little straight ore. In Mexico, a smeltery for the production of star antimony was installed at Wadley, on the National railroads in the northern part of San Luis Potosi, about 1900, and practically all of the Mexican ore is now treated there and shipped abroad as metal."

The Principal supplies of Antimony ore.*

(In metric tons).

	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.	1907.	1908.
Austria	864	679	410	201	126	18	41	103	1,673	1,071	910	193
Bolivia	..	..	1,213	1,174	190	126	59	7	17	571	....	....
Canada¶	Nil.	1,118	?	6	219	13	128	87	340	1,425	2,048	134
China	..	..	..	..	..	..	....	..	....	3,624	2,382	544
France and Algeria	5,466	4,571	7,592	7,963	9,867	9,715	12,380	9 065	12,543	18,567	25,200	26,216
Hungary	1,800	2,201	1,965	2,373	323	748	205	1,080	949	580	2,035	1,316
Italy	2,150	1,931	3,791	7,609	8,818	6,116	6,927	5,712	5,083	5,704	7,892	2,825
Japan	348	1,006	712	81	119	88	153	104	96	97	....	....
Mexico†	5,873	5,932	10,382	2,313	5,103	1,279	1,856	1,775	2,035	2,418	4,615	4,046
New South Wales‡	172	84	332	252	90	57	13	111	394	2,490	1,780	119
New Zealand	10	..	..	5	30	..	....	..	....	....	....	5
Portugal	417	245	59	38	126	68	83	31	84	481	383	76
Queensland	..	..	41	..	..	..	....	Nil.	24	Nil.	Nil.	42
Spain	354	130	50	30	10	67	42	245	77	180	205	124
Turkey	400	§	1,173	267	224	‖ 481	‖ 1,903	298	‖ 188	‖1,036	....	....
United States	454	?	544	300	100	Nil.	Nil.	Nil.	Nil.	267	190	326

* From official reports of the respective countries. † Export figures, except for 1903, which represents production ‡ Metal and ore. § Not reported. ‖ Exported. ¶ Exports for the fiscal year ending 30th June, except for 1906 and 1907, when figures represent production for calendar year."

"The principal antimony refiners in England are Cookson & Co., of Newcastle-on-Tyne, Hallett and Fry, Johnson and Matthey, and Pontifex and Wood, of London; in France, E. Beau, in Alais (Gard), E. Chatillon and V. Geraud, in Brionde (Haute Loire), and the Herrenschmidt Company at Le Genest (Mayenne); in Italy, the Société Anonyme

** The Mineral Industry, 1909, xviii, pp. 35–36.

Franco-Italienne, of Genoa, an important paint and metal producing company which has affiliations in France. In Bohemia and Hungary there are also several important refiners."*

The following Table from "The Mineral Industry," xix, 1910, p. 38, indicates the chief centres of antimony smelting.

PRODUCTION of Antimony Metal in Foreign Countries.

(In metric tons.)

	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.	1907.	1908.	1909.
Austria	343	271	153	114	24	14	36	90	Nil.	207	162	Nil.
China†	..	..	..	..	..	..	..	3,353	3,829	2,316	9,356	7,937
France	1,226	1,499	1,600	1,786	1,725	2,748	2,116	2,396	3,433	3,945	3,850	5,444
Hungary‡	855	940	846	706	683	732	1,007	756	1,322	841	670	.
Italy	380	581	1,174	1,721	1,574	905	836	327	537	610	345	59
Japan	235	229	349	429	528	434	321	190	627	248	198	201

† Exports of regulus and refined metal. ‡ Regulus.

The noticeable feature in this Table is the leading position assumed by China in 1908 and 1909, which is likely to be maintained, for in February, 1911, "all the antimony producers in Hunan Province, China, and in England, &c., were combined. Now the antimony ore and crude product of Hunan will all be treated by the Wah Chang Company and shipped as regulus. There will be no more crude antimony ore for sale, and it is planned to regulate the ore production according to the world's consumption."§

The Wah Chang Mining and Smelting Company's Antimony Refining Works were established in Changsha City, Hunan Province, in 1909, H. Herrenschmidt's process being chiefly used.‖

The Company owns three mines. In one the lode is 6 to 8 feet wide and several hundred feet in length, containing 20 per cent. of antimony. In another the lode is 5 to 7 feet wide, and several hundred feet long, containing from 40 to 50 per cent. antimony, and is opened to a depth of 500 feet.¶

In France which, together with Algeria, is the largest and most consistent producer of metallic antimony, twenty-five mines were at work in 1909, the production of ore amounting to 28,105 tons.**

From the following figures, which are compiled from "Mineral Industry, 1910," vol. xix, page 37, quoted from "Engineering and Mining Journal," of the average yearly price of antimony in New York, it will be seen that with the exception of the "boom" years, 1906 and 1907, a fairly uniform value has been maintained for period mentioned:—

Cookson's, Hallett's, and Others.

	Average prices cents. per lb.
1901	9·13
1902	8·44
1903	6·84
1904	6·88
1905	10·75 (Cookson's and Hallett's only)
1906	22·15
1907	15·77
1908	8·37
1909	7·91
1910	7·83

* The Mineral Industry, 1909, xviii, p. 37. § *Ibid.* p. 41. ‖ *Ibid.* p. 40. ¶ *Ibid.* p. 40. ** *Ibid.*

New South Wales.

The following Table shows the quantity and value of antimony (metal and ore), the product of this state, exported to end of 1910 :—*

Year.	Quantity.	Value.	Year.	Quantity.	Value.
To end of—	tons cwt.	£	To end of—	tons cwt.	£
1880	564 7	11,830	1897	169 2	3,612
1881	539 4	17,346	1898	82 7	916
1882	1,068 18	16,732	1899	326 10	2,694
1883	375 11	5,555	1900	248 8	2,429
1884	433 12	6,458	1901	88 3	1,183
1885	292 15	4,296	1902	56 8	542
1886	273 3	3,381	1903	13 0	135
1887	168 7	1,641	1904	108 17	503
1888	190 7	2,918	1905	388 1	5,221
1889	221 8	3,344	1906	2,450 18	52,645
1890	1,026 0	20,240	1907	1,752 2	46,278
1891	914 17	22,057	1908	117 4	1,141
1892	728 5	14,680	1909	95 9	711
1893	1,774 0	25,092	1910	96 17	1,450†
1894	1,250 7	18,744	1911	165 10	2,010
1895	478 16	7,251			
1896	132 15	1,834	Total	16,591 8	£304,869

* Ann. Rept. Dept. Mines, N. S. Wales, 1911, p. 62.
† Value enhanced by gold contents.

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